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Functioning of the Division of Administrative Officers in 1944-45

By A. A. POTTER
Purdue University

As Chairman of the Division of Administrative Officers during 1944–45, I have given considerable thought to the objectives given of the Division and came to the conclusion that:

1. It should relate the engineering colleges to public welfare by close cooperation with the agencies of the Government.

2. It should bring about cooperation among the engineering colleges in the interest of the engineering profession, industry, and the public at large.

3. It should aid in increasing cooperation between the American engineering colleges and those of other lands.

4. It should cooperate, on behalf of engineering colleges, with engineering societies, trade organizations, and commercial groups in the interest of engineering education.

5. It should be the forum for the discussion of problems which are of general interest to the engineering colleges.

6. It should act as an instrument of inquiry into problems which contribute to effective administration of engineering colleges.

7. It should keep engineering colleges fully informed of legislation and of trends in government and industry, which may affect engineering education.

8. It should aid in keeping the public conscious of the value of engineering education as a preparation for service to society in a technologic civilization.

Keeping in mind the above purposes of a Division of Administrative Officers of Engineering Colleges, the Executive Committee of the Division, or through special committees, considered during 1944–45 a number of matters, of which the following are typical:

1. Contacting the Veterans Administration with reference to Public Law 346 and 16.

2. Conferences with representatives of the Army and Navy with reference to Universal Military Training and Reserve Officers Training Programs in engineering colleges.

3. Special consideration of legislation affecting vocational and general education, engineering research, and extension.

4. Contacts with agencies of government and industry with reference to Surplus Government Property and Procurement regulations.

5. Contacts with the State Department regarding the training of students from other lands.

6. Contacts regarding revisions of

Selective Service legislation to insure a high level of scientific competence for the nation.

7. Cooperation with the Army in nection with an educational program to further preparation for civilian life of those in the Army of Occupation or awaiting shipment home from Europe.

8. Cooperation with U. S. Civil Service.

9. Calling nation-wide attention to the critical shortage of engineers.

10. Cooperation with the Post-graduate School of the U. S. Nava Academy.

11. A study of academic tenure professional services, and responsibilities.

12. Meeting of Division, October 23, 1945.

Eight Administrative Division Memoranda were mailed to the Principal Administrative Officers during the year.

A Division of Administrative Officers is not intended to manage, but to serve as a clearing house for questions, policies, and trends of special concern to engineering colleges.

Northeastern University. — William T. Alexander has been appointed Dean of the College of Engineering at Northeastern University effective December 1, 1945. He will also serve as Head of the Industrial Engineering Department. Dean Alexander takes over leadership of the college from William C. White, who has served as Dean since 1940 and who will remain at Northeastern as Director of its Day Division.

Atomic Engineering?*

By THEODORE VON KÁRMÁN

California Institute of Technology

It has happened now for the third time in our lifetime ("our" referring to the elders of the engineering profession) that new avenues of engineering activities of tremendous importance have been opened by physicists and the engineering profession has found itself unprepared to challenge the task.

In 1887 the physicist Heinrich Hertz discovered "wireless telegraphy." In fact, he experimentally confirmed the existence of electromagnetic waves which anybody may easily read in Maxwell's equations of the electromagnetic field, *i.e.*, anybody who can read equations at all. It took several decades for radio engineering to become a branch of the engineering profession and for adequate measures to be taken to incorporate the fundamentals of field theory into the engineering curriculum.

The discovery of electromagnetic waves of long wave length was followed very soon by the discovery of X-rays, *i.e.*, electromagnetic waves of very short length of a frequency far beyond the spectrum of visible light. It has to be said to the credit of the engineering profession that it took advantage of X-ray techniques in various industrial fields and the design and construction of X-ray apparatus was recognized as an important branch of engineering.

Similarly, the infrared technique, *i.e.*, the technique of waves longer than those of visible light but very much shorter than radio waves, was justly considered as an engineering problem.

However, in the period between the two world wars, physicists made great efforts to narrow the gap between radio and infrared waves. They succeeded in producing microwaves which made possible the marvelous technique now commonly designated as the art of radar. The physical facts were known a long time before the beginning of the recent war. However, during the war, physicists, by their superior knowledge of electronics, *i.e.*, the mechanics of electric particles, were able to solve the engineering problems of producing and directing microwaves. I will not contest the fact that a great many American engineers were sufficiently familiar with electronics; many made important discoveries and contributions to electronic devices. But somehow our engineering education does not encourage the idea of the unlimited horizon, when fundamental thinking in novel fields is required.

And now it seems we are at the threshold of the new atomic age. I do not know whether or not this is true, but certainly we shall have "atomic engineering" in the fields of power and transportation. Are we prepared for the problems involved?

The first application of atomic engi-

*Reprinted from "Mechanical Engineering" Vol. 67, No. 10, page 672, October 1945.

neering was directed by military engineers; plants and many gadgets were probably designed and constructed by engineers. However, not only the discovery of the fundamental facts but also the methods of application were suggested, worked out, and tested by physicists. I concede that security regulations and personal relations in the "nuclear clan" played a great part in the choice of collaborators. However, I raise the question, do we give today to the future engineer enough fundamental knowledge in basic questions of the structure of matter, the nature of energy, the relation between matter and energy, so that he will be able to think intelligently in the new field, to have good engineering judgment on possibilities and methods? Is he better equipped than anybody else who reads a few popular articles in the *New York Times* or in the *Saturday Evening Post?* Is there something wrong in our engineering education? I am afraid there is.

First, I believe we have a tendency to restrict our teaching to scientific knowledge which has immediate applications. We often forget that almost every new physical or chemical discovery *might* have engineering application. After all, engineering is the conquest of nature, *i.e.*, matter and energy, for human comfort, and therefore an engineer cannot know too much about the inner structure of the matter against whose whimsical moods he struggles and the laws of energy which he wants to exploit and harness.

Second, we underestimate the interest of our students in "natural philosophy." We are reluctant to present the fundamentals of physics and chemistry as a living science full of question marks and changing concepts. We believe we ought to introduce the findings of research only after the unshakable truth has been established. We tend to stick to classical concepts. I found while teaching mechanics of continuous media, elasticity and fluid dynamics, my students listened eagerly as I told them something about atomic structure of the materials and kinetic theory of gases. I wonder how many engineering students obtain a picture of entropy, chemical reaction, and the like, from a modern point of view. And why should ordinary combustion be an engineering topic, and nuclear reaction a mystery of modern alchemy?

Third, we overestimate the importance of transfer of experience to coming engineering generations in comparison with a training aimed at true understanding of the happenings of nature. We try to train engineers so that the employer can use them almost immediately after graduation from school. One of my former students was employed as an instructor in a well-known engineering school. He suggested some changes in the hydraulics curriculum in the direction of modern fluid dynamics. His superior asked him the use of teaching the findings of research men who, he conceded, found interesting results in hydrodynamics. None of these men, he said, would be able to design a sewage pipe system. No doubt he was right in this statement of fact, but he was wrong in his conclusion. Fortunately, the more intelligent employers are beginning to realize that immediate usefulness is not the most important criterion of a novice engineer. They appreciate sound fundamental understanding and do not want the school to train for them the type of practical engineer, who—according to the *bon mot* of a prominent Englishman, himself an engineer—perpetuates the errors of his predecessors.

Fourth, I certainly do not wish to make of every engineer a scientist, or, God forbid, a nuclear physicist. However, we shall try to give him an education which shall enable him to follow the progress of science, as, I believe, every medical doctor should have sufficient education to follow the development of biology which has produced in our time almost as spectacular discoveries as physical science. At the institution at which I have been teaching in the last fifteen years, science and engineering students have essentially common curricula the first two years. The physics student continues after that to move on a relatively high intellectual level of understanding natural phenomena from a scientific point of view. I have often wondered why the engineering student has to make a steep drive into an atmosphere in which the beam on three supports is considered a most difficult problem and the exact clear principles of mechanics and thermodynamics are replaced by semiscientific, semipopular "ersatz" truths.

I am convinced that the knowledge of the deepest origins and also the limitations of the principles does not handicap a person in their practical application; as a matter of fact, real knowledge makes the application easier and safer. And after all, physics students are not any more intelligent than engineering students.

I have digressed from the subject indicated by the title. From the little I know and the little I have read on the subject, I really believe that the problems involved in the development of atomic power for stationary and transportation purposes are primarily of the nature of engineering and especially applied mechanics. In other words, the picture of the nuclear processes obtained by the physicists contains so much of the truth, if such thing as truth exists, that from now on systematic observation and computation must lead to practical solutions. Certainly intriguing problems, like the development of materials resistant to extreme temperatures and extreme corrosion, and difficult applications of our knowledge in diffusion and heat transfer, will be involved. However, it may sound paradoxical, but it seems to me that the processes involved in atomic engineering are less complex than, for example, the processes of combustion of conventional solid and liquid fuels; less complex in the sense that simple considerations and theoretical computations may give closer approximations to reality than in the case of molecular reactions. What can appeal more to a scientific engineer?

Washington University—College of Engineering Evolution of a Policy

By ALEXANDER W. BUCHAN
Washington University, the School of Engineering

The "Polytechnic" Movement

In Washington University, the School of Engineering fits more aptly into the original plans of the institution than any other division. The charter of the University, granted, in 1853, "to provide the means of a thorough and complete education, with a particular view to practical usefulness," was taken over by a group of St. Louis citizens who, among them, shared most of the educational enthusiasms of the early nineteenth century. One of them, who became twice mayor of the city, wanted "to combine the advantages of the mechanics' institutes of America with those of the polytechnic institutes of Berlin and Vienna"; his desire was apparently to fashion the young university on the pattern of the Franklin Institute of Philadelphia, in which he himself had been trained. Other members of the Board, frankly on the lookout for more literate workmen in their factories and offices, were willing to back the polytechnic idea to the limit, being anxious, like the incorporators of Renssalaer, to have the sons and daughters of farmers and mechanics taught the uses of science in agriculture, domestic economy, the arts, and manufactures.

Influence of the Lyceum

This enthusiasm for an educated proletariat was tempered, however, by the influence of the lyceums. In their quest for lecturers on scientific subjects, the lyceum groups, proliferating far and wide in the 50's and 60's, had to fall back upon the graduates of the Eastern colleges, and the first chancellor of Washington University, Joseph Hoyt, had lectured on the lyceum circuits of the East before coming to St. Louis. With all its taint of popularization, the lyceum lecture bridged the gap between the craft instruction of the manual labor school and the scientific lecture of the university: by bringing science to the people, it fostered a popular demand for the teaching of science. Perhaps the sale of globes, cabinets, and apparatus to accompany the lectures became something of a racket, but these crude collections were the forerunners of the elaborate equipment of the modern scientific laboratory.

A Place for Science Alongside the Classics

Practical instruction for tradesmen and lectures on science for a democracy —these were the first steps taken toward Washington University. But it was fortunate for the institution that still another educational issue was exciting educators in the mid-fifties, an issue that, as Noah Porter of Yale remarked a few years later, was not merely an agitation for reform but a

thorough-going revolution. What place was to be found in the traditional classical curriculum of colleges for the new and insurgent sciences? In spite of the vested rights of the divinity schools of the East, their own graduates were among the first to recommend the wonders of the new world of science and industry. Hoyt, who attended the divinity school of Harvard College, laid his plans for Washington University as a "place where the student is furnished with every possible facility for pursuing his studies . . . throughout the whole domain of science and letters." Without denying the worth of classical culture, he and William Chauvenet, who succeeded him, insisted on finding a wide space in the curriculum for the basic sciences.

Foundation Laid in the Seventies

When, therefore, in 1856, a Collegiate Department of the University was opened, a laboratory for a Scientific Department was built nearby, and the Practical Department, already in existence, was integrated with this department of science. Like every other educational institution, Washington University suffered during the Civil War; but, in 1870, it graduated from its Scientific Department two civil engineers, and, in the following year, a full-time professorship of Mining and Metallurgy was established and plans were laid for an expansion of what was still termed the "Polytechnic" Department. Two years later, courses were listed in Civil and Mechanical Engineering, in Chemistry, in Mining, and in Building and Architecture. The staff of the young engineering college already numbered fifteen. It may be worth noting, too, that the influence of the Eastern college was still apparent, for an acceptable student of the mid-seventies had not only to pass a thorough examination in English, Geography, History, and other subjects, but he had to display "the manners and habits of a gentleman." Very early in its career, the School of Engineering of Washington University was insisting on a professional ethic among its students and graduates! By 1876, a four-year curriculum was being enforced: a freshman and a sophomore year alike for all students, emphasizing a thorough groundwork in Mathematics, Chemisty, Physics, English, and a foreign language; a Junior and a Senior year of specialization in the particular field of the student's interest. Apart from the inevitable changes within those fields in the last seventy years, this curriculum is still enforced, and the thorough grounding of students in the basic sciences is made a preliminary of their specialized study.

The Formative Faculty

Meanwhile, a succession of energetic scholars and teachers were establishing a high standard of training in the Polytechnic School. Calvin M. Woodward, Professor of Applied Mathematics and Mechanics, was Dean of the School from 1870 to 1896, and again from 1901 to 1910, and, from the beginning, he insisted on rigorous entrance qualifications and expected the students, during their training, to gain actual practice by finding jobs in industry. On this basis of his belief in the close relationship between classroom theory and the work of the shop, he organized and directed for forty years a Manual-training school, under the aegis of the University, which became the model for all such schools both in America and in England.

Closely associated with Professor Woodward in building up the School

CUPPLES HALL I

was Professor Francis E. Nipher who became professor of Physics in 1874 and for many years headed the department of electrical engineering. A man of immense scientific curiosity, Professor Nipher became one of the pioneers in setting up careful weather service throughout the Middle West, and his precise records of magnetic disturbance, rainfall, and other weather phenomena paved the way for the modern science of meteorology. Other well-known members of the faculty in the early days were Professors John B. Johnson, Henry S. Pritchett, and Edmund A. Engler. Professor Johnson, a charter member of the S.P.E.E. and its fifth President, was Professor of Civil Engineering from 1883 to 1898, and his textbooks on framed structures and on materials were standard in their generation. He left Washington University to become dean of the College of Engineering at the University of Wisconsin. Under Henry S. Pritchett, who was Professor of Mathematics and Astronomy, and later the President of M.I.T., the study of astronomy in Washington University was for almost a decade second to none in the country, and his emphasis on the importance of mathematics in engineering is still a noticeable feature of the School. Another excellent exponent of mathematics, still remembered fondly by old graduates, was Professor Engler, Dean of the School from 1896 to 1901, and later President of Worcester Polytechnic Institute.

CHANGES IN THE UNIVERSITY

Near the turn of the century, largely through the instrumentality of Mr. Robert S. Brookings, a thorough reorganization of Washington University was set in motion. An extensive area just beyond the city limits of St. Louis was bought, large sums of new endowment were procured, and a number of college buildings, gifts of Mr. Brookings and his friends, were erected as the nucleus of the present college properties. Among those, the three engineering buildings, Cupples Hall I, Cupples Hall II, and a large engineering laboratory, were the gift of Mr. Samuel Cupples, who contributed some $4,000,000 for construction, equipment,

CUPPLES HALL II

ENGINEERING LABORATORY AND SHOPS

and maintenance. As the result of a further bequest by Joseph B. Givens, in 1932, architecture, which had been linked with engineering, was provided with separate quarters, and the four engineering departments of the School fully occupied the two halls and the laboratories.

Following a drift noticeable in all educational institutions, each department of the School emerged gradually from a parent scientific department in the College. Mechanical Engineering became independent of the Mathematics Department, though a Department of Applied Mathematics is still active in the School. Electrical Engineering, originally a branch of Physics, also became autonomous, and Chemical Engineering more recently received departmental status. By this process of development, the departments of the School, with the exception of Civil Engineering, attained their majority only after a thorough tutelage in the parent science, and their present close alignment with the changing needs of industry has not been permitted to affect this insistence upon a rigid training in science.

THE PRESENT SITUATION

Professor A. S. Langsdorf, the Dean of the School, has been connected with it almost continuously since 1898. After a period of advanced study in Cornell University, he returned to Washington University in the fall of 1901 to organize a new department of Electrical Engineering of which he was head. In 1910, he became Dean of the School and occupied this position for ten years. After a short period of active work in industry, he came back to the University in 1928 to resume his position as Dean. Recognized as one of the country's foremost authorities on electrical machines, he has continued, in spite of his administrative duties, as a teacher in this field and is the author of two standard texts. He has been a member of the S.P.E.E. since 1903 and was a member of the Council from 1913 to 1916.

It will be noticed that, during the seventy-five years of its active existence, the School of Engineering has, apart from two brief intervals, been largely guided by two men, Professors Woodward and Langsdorf, each of whom has contributed decisively to the shaping of policy. To the former, in the late 19th century, the problem was, at least in part, the necessity of justifying in the eyes of industrialists and men of commerce the value of a scientific training for engineers. While Professor Woodward was not in doubt about the relationship between college and the manual-training school, his enthusiasm for the latter was a happy augury, since the skills and elementary theory of the manual training school were clearly useful in the factory. Inevitably, this form of school found its legitimate niche in the public school system, and disappeared as a step in the training of the professional engineer; but it served, and still serves, its purpose of supplying polytechnic instruction to the artisan, the craftsman, and the average citizen. With the new century, however, and the emergence of autonomous departments of engineering, there has arisen the much more complex problem of adjusting the curriculum of the school to rapid advances in technology and to increasing specialization within each field. Curricula tend to become static; invention and research move on.

As early as 1918, Dean Langsdorf began to advocate a program of industrial research along every line of engineering development, but lack of appreciation in industry itself and in the college field made the plan inoperative for a number of years. Individual members of the faculty came to terms with the needs of industry and cooperated with industrial firms on various projects; but the School as a whole was unable until recently to develop its program of industrial research. Within the last two years, because of generous financial support from the industries of the area as well as from the University, an extensive program has been opened up and already several projects are under way. To implement the plan, an additional large building has been designed and will soon be erected to provide ampler quarters for all departments. In this new building the departments of Chemical and Electrical Engineering will have their classrooms, laboratories, and research laboratories, and all of the departmental libraries will be centrally located. As the plan matures, experts in any field of engineering research will be on hand to supervise, for industrial firms, any project of research that comes within the scope of engineering and which meets the criterion of possessing educational and scientific value. By this means, a close relationship, on the highest level of scientific investigation, will, it is hoped, be established between the laboratories of the School and the similar laboratories and the factories of industry. The School expects to provide both the facilities and the personnel required for this research, and, while its staff will retain their standing as independent scientists, the policy of cooperation that began on the "polytechnic" level will be carried on in the upper levels of scientific development.

"You're Never Too Old to Learn"*

By A. R. STEVENSON, JR.

Staff Assistant to Vice President in Charge of Engineering, General Electric Company

The level of a profession can be raised by improving the education of its members; the influence of a profession also depends on unity.

The position which a profession holds in any community depends upon the sum total of the worth of the individual members in that community. If the engineers in that community are narrow-minded specialists, lacking in understanding of the humanities or a concept of the broader things in life, the community is not likely to look up to the profession but will tend to discount whatever the profession represents.

Also if the engineers in the community have too many diverse aims without sufficient common grounds for cooperation their recommendations will lack the unity of purpose which is necessary for any group to accomplish much.

A group of the older, better known, engineering societies some years ago formed the Engineers' Council for Professional Development. This is a *unified* effort and its objectives are largely *educational*. The work of the E.C.P.D. is carried out under four main committees. A Selection and Guidance Committee endeavors to see that the right kind of young men go to engineering schools and that the wrong kind do not; an Engineering Schools Committee contacts the colleges and accredits the courses; a Professional Training Committee stimulates post-collegiate education, and a Professional Recognition Committee is in specific charge of trying to raise the prestige of the *engineering profession*.

These committees were formed because it was held that the level of a profession can be raised only by improving the education of its members, and that the influence of a profession depends to some extent upon unified aims.

In the course of analyzing the place of engineers in society, it was found that there has been a regrettable tendency for these men to form numerous narrowly limited groups corresponding to equally circumscribed professional specilizations. Clear evidence of this tendency can be found in a list of such groups which numbers well over three hundred.

Unify Engineering Education

About half a century ago there were only one or two kinds of engineering taught in the colleges. Today there are under-graduate courses in a host of engineering specialties. But the present tendency for young men to sepcialize in undergraduate work is a limiting educational experience. Such a statement is not made to depreciate the

* Based on an article in the September 1945 General Electric Review, entitled "Technical Education plus the Humanities Makes a Better Engineer."

ulve of special study, but rather to oint out that the various demands of ving and working as an engineer are etter met by the person who gains a eneral basic training and who then evelops special interest in, say elec- onics or refrigeration.

In the General Electric post-collegi- te training program, which comes nder my supervision, we quite frankly ay that we make electrical engineers ut of mechanicals and mechanical en- ineers out of electricals. We forget lmost immediately what a man's col- ge degree is. You will find that some f our best mechanical engineers gradu- ted with electrical degrees and vice ersa. In fact, I discovered, to my urprise, not long ago that one of our rominent mechanical engineers had raduated as a chemical engineer.

In the postwar period, in addition o the other engineering courses which e were giving before the war, we are lanning courses to broaden chemical ngineers and metallurgists. These ourses will have very little chemistry r metallurgy in them. We want to ake all-round engineers out of these en so that they will not get stuck in arrow ruts but will be broad enough o be able to accept any promotion hich falls in their way.

It is interesting to note in this con- ection that Dr. Zay Jeffries, who is a etallurgist, is now a Vice President of he Company in charge of the new hemical Department. It is obvious hat he must know a good deal be- ides metallurgy in order to hold his resent position.

Leadership

To be really successful a young man ust have much more than a narrow echnical education. A technical edu- ation has to do with "things." The people at the bottom of any organiza- tion deal more with "things." The people at the top have to deal more with "people."

Professor J. Duncan Spaeth, who was professor of English at Princeton, was a real leader. He founded rowing at Princeton and was a real leader in this field of sports. In 1923 he gave a talk entitled "Law for Man and Law for Things."* He pointed out that after an engineer has built a bridge it would be foolish for him to pat the bridge and say, "Dear Bridge, for my sake stand firm when the floods come." The bridge is a "thing" and does not respond to emotional appeals but only to hard, cold logic.

One of the precepts which we use in our Human Relations Classes is that *in dealing with people it is not sufficient to be right, one must also persuade.* This is of great importance, particularly to the young engineer whose education has largely dealt with "things:"

This is a material civilization and, therefore, anyone who is going to succeed in it should know about material things and be able to argue logically. He may be right but he cannot accomplish much unless he can persuade others to follow his leadership.

In the period preceding this present war, apparently there was a lack of leadership in this country and in the world. It was lack of business leadership which permitted the depression, and lack of government leadership which prevented the normal recovery from this depression. The war was brought on by a failure of statesmanship.

It is obvious that military organiza-

* News Letter of Princeton Engineering Association given at Eastern State Gas. Conf. at Philadelphia in 1923.

tions require leaders. They make a profession of developing them. It may be that one of the benefits of this war will be the leaders, who have been developed by their military experiences, who will come back and apply their leadership ability in civilian life.

Incidentally, you cannot separate leadership from education. Every army officer is an educator and every executive must be an educator, too.

Dangers of Misdirection

We have not gone far enough, however, if engineers are taught only the art of persuasion. A leader who can persuade others to follow him is very dangerous unless his direction is both scientific and humane. Hitler is the classic example of misdirection.

An officer's guide for the U. S. Army, in an early edition published sometime before 1940, attributes to a distinguished military leader of a past era of the German Army the following classification of officers. According to this legend there are only four classes of officers. First, the brilliant and industrious. They make the best staff officers, for their talents provide maximum service to commanders. Second, the brilliant and lazy. Their tendency to avoid troublesome and time-consuming detail enables them to retain the perspective which is necessary in the art of making decisions. Their plans tend to the simple, the direct, the most promising for easy success. Third, the stupid and lazy. While this group will add little to military lustre, they can be used on small tasks which are necessary to be accomplished. At least, they will do no great harm. They can be retained and used. Fourth, the stupid (misdirected) and industrious. Great damage may result from their actions. Attacking the ill-advised with zeal and energy they may induce a disaster. They are the most dangerous. They must be eliminated.

In the exact sciences it is possible to prove rather conclusively whether something is true or false. In politics and economics, it is very much more difficult to be sure what is good and what is bad.

Pitfalls Avoidable

President Hutchins of the University of Chicago has pointed out that within the last twenty years some of our citizens returning from Italy came back with the idea that Mussolini was doing a very good job. The crime rate was low and the prosperity of Italy had been improved. "He made the trains run on time." Based on short-time experience of something less than twenty years, one might have come to the erroneous conclusion that the principles of Mussolini's government were good and should be emulated. Today, we realize that Mussolini's regime was not based upon good principles, and it has brought horror and suffering to the Italian people. An analysis of historical developments, however, should have indicated that Mussolini's principles were wrong and doomed to failure without waiting for the conspicuous failure which has occurred.

It is certainly advisable that anyone who is going to help guide the affairs of the nation be a student of history. There is the old saying, "There is nothing new under the sun." Most government experiments have been tried again and again. If they failed in the past, they ought not to be repeated in the future unless there is some reason to believe that something different has been included which will overcome the first failure.

By the way of analogy, when Professor Elihu Thomson and Dr. Steinmetz developed capacitor motors forty or fifty years ago, the motors were a failure because there were no good capacitors at that time. With the last twenty years the capacitor motor has been revived and is now a great success because there are good capacitors in production. It would have been foolish to revive this type of motor if there had not been better capacitors than were available to Thomson and Steinmetz.

Thus, if engineers are going to participate in activities outside their technical fields and furnish leadership in the broader affairs of the nation, they must possess not only the ability to persuade but also the knowledge of the right direction in which to lead followers. These skills can be developed by studying and gaining experience in cultural subjects.

Broaden Technical Education With Cultural Subjects

There has been much discussion recently of how the engineering colleges are at the present time trying to "graft the humanities on to the technological stem of education." One may wonder what the humanities are. The humanities include a study of the cultural backgrounds of various peoples, the rise and decline of civilizations, and trends in social and individual human developments.

By Reading

The man who wants really to understand human beings will be immeasurably helped by reading great literature. A book is a great piece of literature if it truly and clearly reflects human nature. A book is valueless in this respect if it is simply an exciting story intended to pass the time away and does not truly and clearly reflect real human qualities.

Never Too Late to Learn

These remarks on the merits of a broad education may lead some graduate engineers to feel that having had a narrow technical education they can hope only to be specialists. Some people have the erroneous idea that youth is the time for all education. Shortly after the First World War, I heard a psychologist * remark that tests on the soldiers showed that men reach the peak of intelligence at 24 years of age and go downward thereafter. His statement may be true for the large masses of people who cease studying at an early age, but it is both pessimistic and wrong to conclude that study in later life is fruitless. The mind is like a tool and if one stops making intelligent use of it, it will become dull and rusty. On the other hand, there are outstanding men whose minds are as keen as razors, mainly because they have kept them sharpened by strenuous use.

By Study

Probably most successful men feel that they have learned immensely more since graduation from college than they ever did in their undergraduate days. This is true in technical fields; and it is particularly true in the humanities. One can learn the exact sciences in colleges because they require no experience of life for their understanding; one can obtain an introduction to the humanities in college, but the humanities to be properly studied must be illuminated by experience of life.

* I don't remember the name of the psychologist but the same idea is expressed by Thorndyke in his book "Adult Learning."

Most older engineers will acknowledge that when they were in college they gave little thought to the humanities. They were absorbed in engineering and the exact sciences. This interest lasted for perhaps ten years out of college. Only a few men remain engrossed in highly technical things to their dying day, as did Dr. Steinmetz, for instance. On the contrary, most men gradually become more involved with people than with things. This shift in interest arises both because executive responsibility makes it necessary and because adult living broadens one's outlook.

It is probably true that most older engineers, ten or twenty years out of college, do not study science and mathematics in their leisure hours but are much attracted by history, literature, politics, and economics. The exact sciences are, of course, important, but the moment that the young engineer interests himself in the broader cultural subjects, he is more likely to get ahead. Of course one must know one's specialty but to a great extent progress will depend on the other things which one knows also.

Make Security, Prestige, and Wealth By-Products of Vigorous Life

Many men gradually come to the conclusion that the most worthwhile things in life arise as by-products of responsible living.

Most books on the history of philosophy indicate that one cannot get happiness by making it the chief goal in life.

Unfortunately, in our society, we all tend to put a money value on everything. Some may wonder, "How can I get rich by learning these cultural subjects?" They can be best answered with the persuasive prospect that they will be better, happier men, and more of a force for good in their communities if they will study and learn to contribute more to the community. As a by-product, they may get more power, prestige, and wealth.

The individual, or corporation, or industry that puts service first is more likely to be a success than one who is always saying, "What do I get out of this?"

Frequently, along with the results of inventive pursuit, useful by-products are developed which may prove, over a period of years, even more valuable than the accomplishment of the objective sought. In fact, great discoveries sometimes spring from apparently unrelated scientific developments.

A devitalizing element in our national thinking during the depression was our paralyzing fear of insecurity. Anyone who makes security his chief aim in life is almost sure to lose it. The man in the Bible who took his one talent and wrapped it in a napkin and buried it in the ground to keep it safe had it taken away from him. The man who took his five talents and adventured with them in the business world doubled his money. One of the hindrances to recovery from the depression was that those who had money tried to save it. If, during the depression, more companies had done like the Pennsylvania Railroad which borrowed money in order to electrify, the whole business world would have been healthier.

The French built a Maginot Line, harboring the illusion that this alone would guarantee their security, and it may have been partly this false sense of security and its resulting complacency which made them an easy prey to the Germans.

It is the hope that engineers will not strive for security so assiduously that they fail to recognize opportunities available to them. Every practicing engineer should make as his habit the study of something each year of his life. Some of this study may be done informally at home, some in night schools run by colleges in some communities, and some may be done in classes run by the company in which the engineer is employed.

Engineering societies have made great strides in the past few years in establishing higher educational and professional standards for engineers. It is up to each person who is a member of the profession to educate himself to assume a role of responsibility to the group and to the community.

Sir Richard Livingstone * has made a fine plea for adult education. He is trying to persuade older men of great ability to actually leave their jobs for a few months at a time in order to broaden themselves and sharpen their wits by intensive education.

. . . When it is realized that periods of systematic study are as necessary to the intellectual vigour of the mind, as periods of recreation to the health of the body, such periods will be recognized as a necessity, in order to avoid a different kind of breakdown, chronic and unrecognized, from what at present many officials and officers suffer. No one would hesitate to forgo the immediate use of money, if by parting with it six months he could earn an ample return; and, if there is any truth in my arguments, the return will be ample, and the abler the official, the ampler the return, both for the man and for the body which he serves. A man lives with details and immediate problems in the narrow deep-sunk pit of his daily work, and needs at times to climb out of it and look around; to see not only the department with which he is concerned but his occupation as a whole, and that occupation's place in the wider order of things; to remember that principles should guide individual decisions and to consider what these principles are; to study related problems and methods in other institutions and countries. Every moment the crust of routine is forming over the mind, thickening, and impairing its fertility; only a continually renewed activity of thought can break it up. . . .

* Quoted from the first essay entitled "The Future in Education" from a book entitled "On Education" by Sir Richard Livingstone, President of Corpus Christi College, Oxford. Published in New York by the Macmillan Company.

Objectives of a Laboratory Course in Airplane Structures

By N. J. HOFF

Associate Professor of Aeronautical Engineering, Polytechnic Institute of Brooklyn

Introduction

The importance of the airplane in combat and transportation was so amply demonstrated during the war that in the next few years every engineering college is likely to make an effort to include in its offerings at least one or two areonautical engineering courses. In schools having no department of aereonutical engineering airplane structural courses may well be given in the civil engineering department. They are of definite value to civil and mechanical engineering students who may never design or analyze an airplane because they help to broaden the student's understanding of structural and stress problems.

In an earlier paper * the writer discussed material to be included in a lecture course in airplane structures. Here he wishes to present a few ideas related to an airplane structures laboratory course. In his opinion the following are the specific objectives of such a course in the order of their importance: (1) Illustration of airplane structural theory; (2) Comparison of theory and experiment; (3) Development of the student's skill in experimental technique.

* Course Content in Aircraft Structures, Journal of Engineering Education, Vol. XXXII, No. 10, p. 833, June, 1942.

Illustration of Airplane Structural Theory

Since all theory is based on fundamental assumptions derived from the results of experiments, theory can hardly be fully understood and appreciated without personal experience with experiments. As a striking example in the field of airplane structures the conception of the shear center might be mentioned. The shear center is defined as the point of the cross section of a beam through which the shear force must pass in order that the beam be only bent and not twisted. In the case of a doubly symmetrical section the shear center coincides with the centroid. However, when the section has a single axis of symmetry the shear center is often "outside" the section proper. For instance the shear center of a thin-walled semicircular open section lies on the axis of symmetry of the section a distance $(4/\pi)$ r from the center of the circle, that is about $0.273r$ outside the semicircular section as can be shown easily by calculation. The writer has never yet know a student who could imagine that the beam of semicircular section in Fig. 1 twists to the right rather than to the left when a load is applied to it as shown in Fig. 2a. However, the student must recognize that the theory

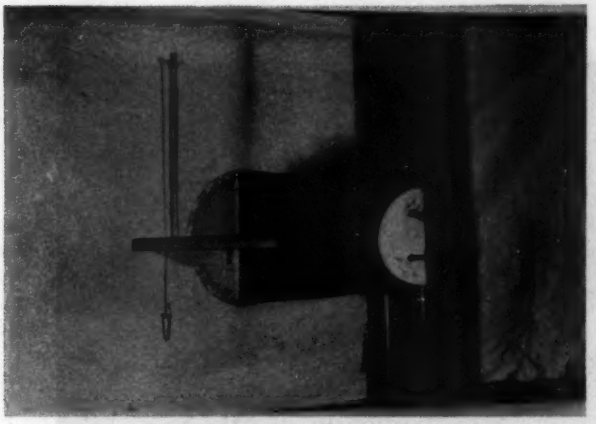

FIG. 1. Cantilever beam of semicircular open section. Plumb line indicates vertical direction.

is correct when he sees the test. In Fig. 2b the load is applied at the shear center and consequently the beam is bent but not twisted. In Fig 2c the point of application of the load is to the left of the shear center with the result that the beam is twisted to the left as well as bent. In the case of the problem of the shear center, therefore, a simple and inexpensive experiment contributes materially to the understanding of the subject.

A similar situation arises in the study of the buckling of thin-walled open section columns that fail by twisting rather than flexure. The beginner in the theory of structures may have difficulty in understanding that at the critical load an originally straight symmetric column fails in flexural buckling, that is by bending sideways. His reluctance to accept the correctness of such a prediction can usually be overcome if the effect of unavoidable initial eccentricities of the load application is pointed out. It is much more difficult to persuade him that under the action of end compression an initially straight column of thin-walled open section may "twist away" when the critical value of the load is reached. The only way to make him accept it is to show an experiment (see Fig. 3).

As a third example the buckling of a framework might be mentioned. The well known fundamental cases of the buckling of a straight bar corresponding to two pin ends, two rigidly fixed ends, one end fixed and one pinned, etc., are so imprinted in the thinking of the structural analyst that he has great difficulty in understanding that there is a strong interaction between the individual members of a framework when they are connected by welding or riveting. It might even be better to say that so far as buckling is concerned the framework has no individual members. None of the members will buckle "first" but whenever one member buckles all the others must distort simultaneously. Fig. 4 is a photograph which illustrates this point. The test setup is shown in Fig. 4a.

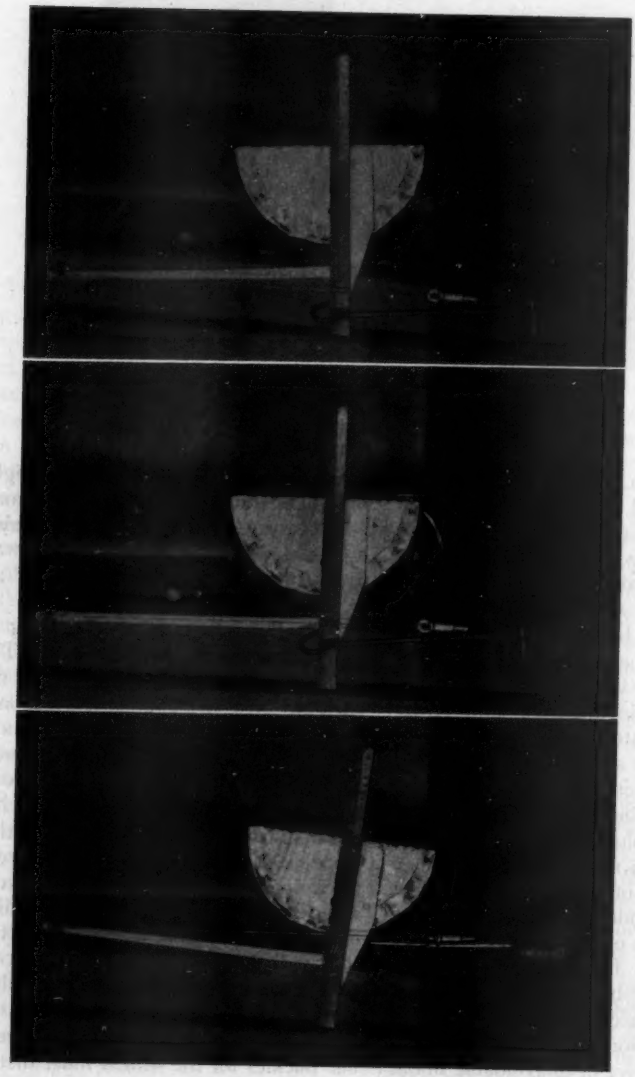

FIG. 2a. Weight to the left of the section. Yet the beam twists clockwise since the load is applied to the right of the shear center.

FIG. 2b. Weight at shear center. Beam does not twist.

FIG. 2c. Weight to the left of shear center. Beam twists counterclockwise.

Comparison of Theory and Experiment

In some of the older branches of engineering where materials and methods of construction have been standardized, loads rigidly prescribed, and methods of analysis stipulated by federal, state or other agencies, it might be possible to teach the student set rules of design and analysis which he has to follow in order to arrive at a structural design satisfactory in service and to the purchaser. Airplane structural design, however, is still in such a fluid state that rules of calculations considered perfect today might be found sadly in error and useless tomorrow. Because of this situation the student of airplane structures should acquire an understanding of the choice and the limitations of the fundamental assumptions upon which theories are developed and learn how to judge the reliability of the theoretical results. An excellent aid in obtaining this knowledge is the calculation of numerical examples and the comparison of the results of the computations with the results of experiments carried out in the airplane structures laboratory. The student should be taught to appreciate that theory is acceptable only if its predictions agree with reality. On the other hand he must also learn to understand the inaccuracies and shortcomings of the experimental approach.

The primitive experiment shown in Figs. 1 and 2 yields almost perfect agreement between the theory of the shear center and the actual behavior of the semicircular thin-walled beam. In the case of the buckling of the fuselage framework of Fig. 4 tested at the Polytechnic Institute of Brooklyn the comparison was neither so good nor so easily obtainable. The theoretical buckling load was calculated using the criterion of the convergence of the Hardy Cross procedure, but it was found slightly lower than the experimental value because the actual framework was stiffer than the idealized one underlying the analysis. The principal reasons for the discrepancy were: (1) In the theory each tube was represented by its center line and was assumed to have a constant flexual rigidity over its length. In reality the ends of the tube were more rigid because of the cluster of converging tubes welded into a single unit near the theoretical end point of the tube; (2) The stiffening effect of the reinforcing lugs at the attachments of the framework to the test stand was neglected; (3) The

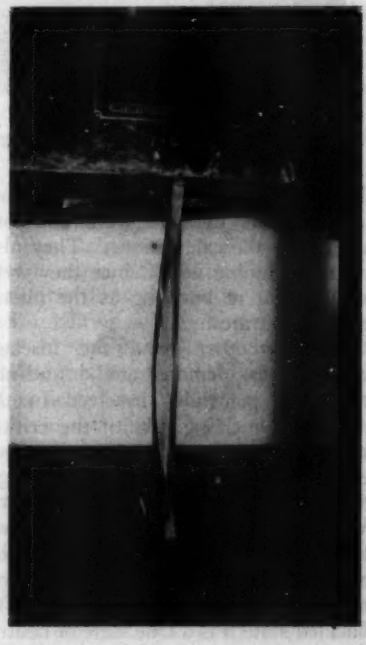

Fig. 3. Channel section twisted under the action of axial compression.

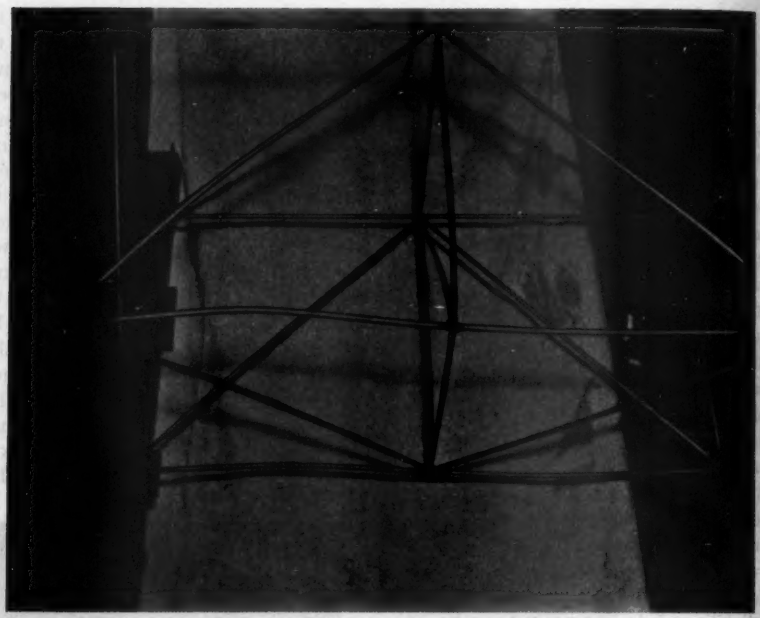

FIG. 4. Buckling of a welded framework.

diagonal bracing elements in the bottom plane of the fuselage were not considered in the calculations. They also had a stiffening effect since they were visibly bent at buckling as the photograph illustrates.

On the other hand the fuselage buckling test demonstrated beautifully the basic principles involved in the theory of buckling. Until the critical value of the applied load was reached each load corresponded to one single deflected position of the framework. When the buckling load was reached, however, the deflections could be increased materially without any noticeable change in the applied load. The buckled state was a true state of neutral equilibrium and the end point of the loading triangle could be pulled down an inch and moved back again while the registered load remained unchanged. Moreover the deflections of the structure were purely elastic. When the load was completely released the framework regained its original state. As a matter of fact the buckling test was carried out a number of times in several classes with the same structure.

In the case of the torsional buckling of a thin-walled open section as shown in Fig 3 good numerical agreement between the theoretical and the experimental buckling load cannot as a rule be had. The main reason for the discrepancy can be found in the end conditions which do not correspond either to rigid end fixation or to ideal pin ends. On the other hand very good

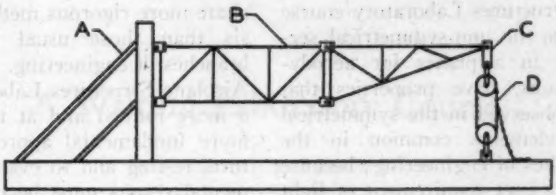

FIG. 4a. Test setup for buckling experiment of framework fuselage. A is the test rig, B the welded space framework, C the calibrated load link with metalectric strain gages cemented to it, and D a hoist for applying the load.

qualitative agreement can be obtained. The theory predicts flexural buckling when the column is long and torsional buckling when the column is short. The change from one type of buckling to the other can be verified by carrying out tests with a set of columns of the same section and of different length.

DEVELOPING AN EXPERIMENTAL TECHNIQUE

It is not the purpose of a college course in Airplane Structures Laboratory to train first class laboratory technicians. Nevertheless the student should acquire the basic techniques, obtain some facility in using his hands, and learn about the instruments and procedures available for carrying out successfully tests on structural elements of aircraft. He should also learn how to plan, organize, and execute a testing program. At the Polytechnic Institute of Brooklyn it was found that students develop the greatest interest in their laboratory work if they are made responsible individually for performing one or more experiments. Each student is given a problem for which he is required to read the available literature, prepare test specimens, and rig up the test. In the class when his experiment is scheduled he gives a short introductory lecture and then either carries out or is in charge of the group that carries out the test.

As a rule an Airplane Structures Laboratory course is taken after the student has had a laboratory course in testing materials. He already knows how to operate the basic types of testing machines and has to learn only the techniques peculiar to airplane structures. The most important of the particular instruments is the metalectric strain gage which is one of the indispensable tools of the experimental stress man in aeronautics.

FURTHER CONSIDERATIONS

Every laboratory course, including one in airplane structures, makes possible the development in students of such qualities as carefulness and patience in setting up experiments and making readings, a critical sense in evaluating results and comparing them with theory, clarity and good style in presenting results in the form of a written report, etc. Since these advantages can be gained from every laboratory course they need not be discussed here. It might be mentioned, however, that airplane structures are subject to the same laws of mechanics as are the elements of structures and machines of civil and mechanical engineering. It is useful to offer a separate

Airplane Structures Laboratory course only because the non-symmetrical sections, used in airplanes for aerodynamic reasons, have properties that cannot be observed in the symmetrical structural elements common in the other branches of engineering; because the stringent requirement of light weight leads to the use of slender and thin-walled structural elements which show instability phenomena not encountered elsewhere; and because the simultaneous fulfillment of the requirements of light weight and safety necessitate more rigorous methods of analysis than those usual in the older branches of engineering. Hence in the Airplane Structures Laboratory course a more refined and at the same time more fundamental approach to structural testing and to evaluating experimental results must be presented than in the usual materials testing courses. For this reason the Airplane Structures Laboratory course should be recommended as an option to all engineering students who wish to acquire a deeper insight into structural problems.

With the largest freshman class since 1918, **Case School of Applied Science** has made numerous additions to its teaching staff. President William E. Wickenden has announced the following appointments: E. G. Kirkpatrick and George Marinoff as instructors in Engineering Drawing; F. D. Parker, instructor in Mathematics; W. P. Rusterholtz, instructor in English; and Earl C. Gregg, instructor in Physics.

In addition five former professors on the Case faculty have returned to the college from various research assignments. Robert S. Shankland, on leave for the past three years to the Office of Scientific Research and Development, has returned to his position as Head of the Department of Physics. Robert Rinehart, Charles C. Torrance, Paul Guenther, and Lewis J. Green have resumed their duties in the Mathematics Department.

Enrollment in the Day Division at the engineering college shows an increase of seventy per cent since July 1, and the Evening Division has increased thirty-five per cent over the figure of a year ago. One out of every three undergraduates in the Day Division at Case is a veteran according to Robert R. Slaymaker, Dean of the Junior Division.

A Writing Laboratory Course

By FREDERICK ABBUHL

Acting Head, Dept. of English, Rensselaer Polytechnic Institute

The fluid state of courses and personnel during the war years has led us in the English Department at Rensselaer Polytechnic Institute to justify a little experimenting. One result is a new elective course that might be of interest to others who are teaching English to engineers. It is not claimed that this is a revolutionary discovery in the methods of teaching composition, nor that others have not attained similar results by the same method or by various methods. We merely pass on our own experience for whatever it is worth. Although we call it Writing Laboratory, it is not a remedial course, and it is not the well-known one in which the student comes to the laboratory to work under supervision day after day on an extended problem. Briefly, it is a course in which we hand the student a mimeographed sheet on which is set forth the problem which we have found in a piece of writing done by an expert. The student works out his own solution within one class hour. During the criticism on the following day the student is shown the expert's work. In the present stage of the course, no formal instruction is given before each new type of exercise. The student learns first by doing and then by participating in the critical post-mortems. The course was last given in three cycles, each cycle repeating somewhat similar problems conditioned by varied factors.

Of course, not all the problems have been derived from actual examples of expert writing. Some were made up from typical situations confronting the young executive, such as letters involving delicate points of tact, press releases, advertisements aimed at various audiences, or short articles interpreting technical facts for the layman. Some elementary exercises involve the use of the dictionary; others require rewriting faulty sentences and paragraphs which have actually appeared in print. By following various periodicals and by consulting a number of editors and corporations we were able to develop a series of problems that are fairly representative of the different writing situations that are likely to confront an executive in a junior position.

The problem sheet contains all necessary directions so that none need be given during the hour. One of the incidental objectives is to develop a capacity for following directions precisely. Since the assignment calls for perfect concentration, s t r i c t silence must be maintained. No communication is allowed, and no assistance is given during the writing. The main educational objectives are stated at the beginning of the sheet. The assumptions come next, followed by a brief statement of the problem. At the close a few specific directions are given. To insure clean copy, the student is required to have a dictionary at his table

to verify the spelling and a handbook to verify grammatical and rhetorical usage. After the critique has been given, occasional period is set aside for correction and rewriting. When rewriting cases accumulated, some of this work has been done at home. The student keeps an account of his typical errors so that he may acquire better habits of correctness.

The exercises which follow will show how the problems are set up and will give some indication of their nature.

PROBLEM NO. 19

Purposes:

1. To give training in adapting technical material for lay readers, as executives or a board of directors.
2. To give training in translating the abstract into the concrete.

Assumptions:

1. You are to write a short article explaining the Bernoulli Effect in Physics for the readers of the *Saturday Evening Post.*
2. The Bernoulli Effect in Physics has been defined as follows: "The pressure in a rapidly moving fluid decreases as the speed increases." (Dunning and Paxton: "Matter, Energy, and Radiation," p. 430.)
3. One method of adapting material for a lay audience consists of giving concrete applications of principles familiar to the readers.
4. Another method consists of presenting to the reader simple demonstrations which he can himself perform with simple equipment which can be found in any home.
5. A third method consists of writing in as lively a manner as possible.

The Problem:

Write an article of about 250 words explaining the Bernoulli Effect, which would interest readers of the *Saturday Evening Post.*

Procedure:

1. Cast your article in two paragraphs.
2. In the first paragraph explain the Effect by presenting an application drawn from nature, industry, the household, or sports.
3. In the second paragraph explain the Effect by telling the reader how to perform a simple demonstration.
4. If at the end of 5 minutes you cannot think of any applications or demonstrations, ask your instructor for some.
5. Write in as interesting and lively a manner as possible.
6. Select and put at the head of your article a title that will catch the reader's attention and make him want to read the article.

PROBLEM NO. 21

Purposes:

1. To give practice in interesting laymen in a technical fact.
2. To give practice in stimulating the reader's emotions.

Assumptions:

1. That during the year more pedestrians are killed by automobiles in the month of December than in any other month.
2. That most of the deaths occur between the hours of six and eight in the evening.
3. That the article will be published early in December.

The Problem:

Write a 250 word article that will by arousing emotion make the reader careful during the month of December.

Procedure:

1. Devote the first 125 words to dramatization; that is, a single scene such as might appear in a short story.
2. Devote the next 75 words to a statement of the facts given in the assumption.
3. Devote the next 25 words to a direct exhortation to the reader.
4. Devote the last 25 words to a reference to the dramatization and a final warning.
5. Number the four sections.

6. Pick a title which will attract the reader's attention.
7. Count the words and put the total in parentheses at the end of the article.

PROBLEM NO. 15

Purposes:

1. To give training in tact.
2. To give training in approaching prominent people.
3. To give training in persuasion.

Assumptions:

1. As secretary of a local society of engineers, you have been asked to invite a prominent engineer to address your group.
2. You do not have funds available for paying a speaker.
3. You do, however, have funds enough to pay travelling expenses.

The Problem:

1. Write the letter inviting the prominent engineer to address your group.
2. Make the engineer understand that his travelling expenses will be paid, but that he will receive no fee for speaking.
3. Make him feel that addressing your group is worth the time and effort he will spend.
4. Be courteous, cordial, and tactful in your letter.

These are the points in its favor which have led us to continue offering the course:

1. For most students an intense, brief experience is likely to leave a greater residue of the capacity he is trying to develop than he could attain by a more leisurely approach.

2. The method develops a respect for time. If he were given the problem to solve at home, the average student would fret over it for several hours.

3. It makes self-discipline imperative, and leads to a degree of self-confidence the student had not attained before.

4. No outside preparation is necessary.

5. It teaches the writer to say, with language economy, what he wants to say and to get from the reader the reaction he set out to get.

6. It develops through the simpler, early exercises a capacity which aids in the solution of more abstruse problems involving extreme finesse and tact.

7. The method provides vital motivation so that the student is intensely interested in many of the problems.

The ideal room in which to give the course would be a spacious well-lighted one equipped with especially designed desks or adjustable tables. We had to use an engineers' drafting room furnished with level-top desks and high stools. Although some students believed that the stools help keep them alert to needlepoint concentration, we would have no objection to easy chairs if they could be provided.

Finally, you should know the typical student reaction to the course. Although he admits he works harder during the laboratory hour than in any normal recitation, he believes the results are worth the effort. The challenge afforded in working out original solutions leads him to recommend that we should never make his task easier by suggesting the professional solution before he has wrestled with his original interpretation. He says he learns to think fast and accurately and to write fluently and correctly. Above all the course bolsters his confidence in handling all kinds of writing requirements he is likely to meet. In short, the method gets results.

The Functions of History in the Engineering Curriculum

By STUART W. CHAPMAN

Associate Professor of History, Carnegie Institute of Technology

History has been all things to all men: a study of "past politics," of class warfare, or of civilization in all its aspects; a depressing series of dates, battles, and treaties or an inspiring account of human achievement; a basis of tales of historical romance or a background for major social decisions. Since the study of history can function in so many ways, its place in engineering curricula must be determined not so much by the nature of the subject itself as by (1) the general objectives of engineering education and (2) the assignment of functions to courses at the individual institution.

The objectives published by the special committee of the S. P. E. E. in the JOURNAL OF ENGINEERING EDUCATION, March, 1940, imply a prominent role for the study of history. An "understanding of the evolution of the social organization within which we live and of the influence of science and engineering on its development" can be obtained only through some type of historical study. The "ability to recognize and to make a critical analysis of a problem involving social and economic elements, to arrive at an intelligent opinion about it, and to read with discrimination and p u r p o s e toward these ends" can be fully developed only if an historical sense is encouraged. The organization and expression of thought lucidly and convincingly can be practiced in history; masterpieces of literature and an understanding of their setting and influence may be approached through it; moral, ethical, and social concepts can only with difficulty be separated from it. The attainment of an interest and pleasure in these pursuits should be assisted by history as by any subject.

A glance indicates that these six objectives for the humanistic-social stem of engineering education emphasize three major interests: (1) methods of thought, (2) knowledge and understanding, and (3) attitudes. The study of history can make a definite contribution to the attainment of each of these fundamental goals.

METHODS OF THOUGHT

With respect to methods of thought the two stems of engineering education—the scientific-technological and the humanistic-social—are actually one. Both should emphasize the same types of thinking, although they achieve the common goal by the use of different kinds of material. Fortunately, the essentials of good thinking are much the same in all fields. One must analyze a problem to become familiar with its nature, parts, and the relationship of the parts. He must devise a plan for arriving at a decision about the

problem in some purposeful and orderly fashion; he must execute the plan with proper regard for the principles involved and for valid, pertinent evidence. He must reach a decision and check his answer for relevancy, accuracy, and adequacy. Finally, he should examine the new knowledge he has acquired to learn what may be of use in future problems.

The study of history, particularly in the form of historical analysis, should encourage the use of sound methods of thought, especially of inductive thought. While it is true that historical induction differs from induction in the natural sciences because experiments cannot be conducted and conclusions are not universally applicable, the two have much in common. Both require a knowledge of how to gather facts, how to criticize and evaluate them, and how to arrange them so that they constitute evidence and have meaning apropos of the problem at hand. It should, therefore, be the special function of history to help the student acquire skill in the collection and use of evidence—in other words, in inductive thinking. In this way the study of history should aid the student in engineering work which demands that method of thought. Conversely, any such skill acquired by the student in his technical work may help him in the consideration of historical and social problems.

The fact that conclusions regarding historical problems are rarely absolute or universally applicable may, in a sense, be a positive advantage. In all of life, problems arise for which there may be neither an exact nor a single solution. Nevertheless, possibilities and probabilities must be considered, judgment must be exercised, and decisions must be reached. The engineer who never encounters such questions in his field is probably doing only routine work.

Time limitations and other factors may make difficult the presentation of such problems in technical courses. Engineering students, however, must be confronted with them, must realize that they do and will arise, and that the judgment and imagination called for in their solution are essential parts of good method. A special contribution can, therefore, be made by history (or for that matter by any of the social studies) in the consideration of problems where good use of evidence must be combined with judgment and creative imagination in order to obtain a reasonable answer. More extensive assignment of technical problems involving the same elements would, it seems, encourage judgment and creativeness to a degree not yet achieved in present engineering education.

Knowledge and Understanding

Fortunately, during the past generation historians have broadened their former narrow political and military approach. They now draw from every field the materials which describe all man's activities, the ways in which they have developed, and the reasons for their growth. Political institutions and processes still occupy much attention; but historians concern themselves also with economic institutions and processes, with science and technology, with the arts, religion, literature, and with the family and other social groups. Not only institutions but ideas are considered; some historians attempt to weave all of these threads of human activity into a descriptive pattern which will show their interrelationships.

In the wealth of materials available to and in the study of history, there is

much that can be used in engineering curricula. Since methods of thought cannot be divorced from knowledge, the student will, of necessity, absorb some facts while he is learning method. It is essential that such facts be significant and that they increase understanding of the modern world if we are to conserve the time allotted to humanistic-social studies.

Just what knowledge and understanding should be imparted by a course in history? One goal should be an understanding of the bases of human activities. The fact that this will involve some consideration of biology need not be disturbing, since without biology there would be no history. Man must be placed in his setting in the world of beings. He must be seen as an animal possessing characteristics and drives in common with others but also as an animal possessing peculiar powers and potentialities.

History is, after all, the story of the many things man has done with his biological equipment; it is an attempt to explain and to give meaning to that story. In its study is found evidence of the potentialities of man; of the many institutions he has created and the forces behind those creations; of the techniques and processes he has invented and the ideas he has devised. In history man appears as a rational being and as an emotional creature, making and resisting change, plodding and giving himself to flights of imagination, loving and hating, destroying and building. Above all, he appears as a creature endowed with a specific human nature which enables him to live with others and to create, as a result of that fact, a culture.

The study of history will make a great contribution to the education of the engineer if it clarifies for him the nature of the human being and of the processes, institutions, and techniques which man develops in order to live and to live better. It will help him to understand the drives, desires, and aspirations which motivate human conduct. It will make more obvious which of them arise directly out of man's biological equipment and which result from his experience in a particular society. It will help him to evaluate ideas and institutions of his own time in more precise terms of their serviceability to his group and to the world. Such an understanding of the background of human action, individual and group, should equip the engineer to deal more effectively with questions involving the human element, whether they concern industry or the community. Every course in history might well attempt to lead the student to this goal as its contribution to an understanding of problems of an economic and social nature.

The study of history certainly should not be restricted so as to result only in the acquisition of the general type of knowledge and understanding just outlined, although the course might justify itself if it achieved nothing more. The citizen of today, however, can profit from a specific comprehension of the development of contemporary institutions, processes, and ideas. Primarily he must perceive the complex interrelationships among the various aspects of the modern world. He must realize that, in many instances, economic problems have political implications and may well require political action. He must be aware that economic activity involves not merely land, labor, and capital but also ideas in which so seemingly remote a thing as religion may play an important part. Likewise, a

real understanding of modern society must rest upon the knowledge that politics is not merely a matter of voting, parties, and constitutions, but that it is a necessary activity intertwined with techniques, with social ideals, with economic interest, status, and influence, with religion, with education, and with all of the other diverse interests and activities of man. Lacking such a comprehension of the interrelatedness of the elements of culture, neither the engineer nor anyone else will be in a position to approach a social problem with realistic appreciation of its many aspects.

The sort of knowledge and understanding which can be imparted by the study of history can be even more specific than this, but its exact nature will inevitably depend upon decisions made at the individual institution on the basis of staff, over-all curriculum and objectives, the sequence of learning, and other factors. For example, if it were decided that engineering students at a particular college should obtain knowledge regarding economics, political science, psychology, and certain phases of biology and sociology, then the specific emphasis for the course in history would be determined in the light of the whole program.

It might be that the course in history could accomplish most if it strove to develop certain concepts of biology and sociology (*e.g.*, evolution, race, and culture) and to impart special knowledge and understanding regarding the development of economic institutions, processes, and ideas. Out of history the student might secure a knowledge of the nature of the economic problem; of the growth of institutions and processes of production, market, and labor; of the relationship of techniques, capital accumulation, population, and governmental activity to the growth of economic institutions; of the persons and institutions who have participated in the making of economic decisions; of the values and theories which underlay economic institutions and processes; and of the success of the economic system in solving the economic problem. In the consideration of these general topics there would be room for a discussion of such specific things as the nature of ownership and management, factors of production, units of production and consumption, reasons for exchange of goods and services, money, self-sufficiency vs. market exchange, competition vs. monopoly. Examples of economic principles could be found in the cultures of many different peoples at different times.

But economics should never be considered in a vacuum. It should always be regarded as merely one part in a way of life, influencing and influenced by every other aspect of the culture of the period. A history course devised and taught in this way should give valuable knowledge and understanding of historical processes and principles. It should also send its students on to the study of economics with a foundation for a knowledge of economic principles and for an understanding of those principles as expressions of human experience rather than as mere static laws.

In another institution particular stress might be placed in a similar way upon political phases of culture. In another, the courses in economics and political science might be regarded as so important that time could be found in them for the consideration of historical backgrounds; then it might be the function of history to emphasize above all else the development of technology and science and their influence

upon the growth of modern culture. The study of history in the largest sense embraces so much that the course in history can be used in a variety of ways according to the needs of the particular curriculum.

The history course in an engineering school can hardly be complete unless it develops (1) some general concepts and (2) more detailed knowledge and understanding of some phase of culture. A political history, an economic history, or a military history could not possibly serve the whole purpose. The immature student could not secure from any of these the great value of seeing the diverse motives, the variety of practices and institutions, and the infinity of interrelationships which become apparent in a broader course. On the other hand, a broad course which resulted in nothing but knowledge and understanding of g e n e r a l concepts would be inadequate. It might never deal with enough specific factual material to enable the student to draw his own conclusions. It would diminish the possibility of showing the dynamic quality of human life and culture by failing to illustrate it in a particular phase of activity. It would deprive the student of knowledge and understanding which would be valuable to him in a subsequent course.

The outsider can only suggest possibilities regarding the general concepts and the special phase of culture which should be considered. In the final analysis, any decision must be made by the individual institution. Teachers of history should welcome consultation with their colleagues in other departments, since by that method the course in history could be pointed up, its job made clearer, and the instructor's sense of participation in a common educational project be made keener.

Attitudes

The study of history, as of any subject, falls short of its ultimate goal if it merely gives knowledge and training in methods of using that knowledge. Attitudes are as important functionally as either of these. Mere possession of knowledge and method carries no automatic guarantee that they will be used for humane and socially desirable ends. Assurance can be given only if the individual respects both himself and other men. Such an attitude must rest on a foundation of belief in the value and dignity of human life.

These attributes are clearly shown in history. They become apparent at once when man is placed in his biological setting; he appears as the only creature who can think of himself as having those qualities and the only one who can set up standards of right and wrong. History should assist the student in understanding that the human being is born not with the destiny to be either good or bad by any absolute standard but merely with the ability to think and act in ways which men may regard as good or evil. His moral potentialities are such as early people were willing to assign only to the gods; they enable him to set up standards of conduct and to take steps to live by them; they give to man a value and dignity above all other forms of life.

History depicts man as the only creature, visible and tangible, who is creative and can establish new ways of life for himself by thought and rational action. It illustrates the many uses man has found for the earth's resources, the new techniques he has devised, and the ideas and aspirations he has developed. His great accomplishments are fully as evident and notable as his shortcomings. If history indicates that man has only inadequately

realized his possibilities, it also proves that his potential achievements have no bounds. Man emerges realistically as a whole, a compound of failures and successes, of inertia and ambition, of limitless interests, of ability to dream and to invent new ways of reaching his aspirations. History proves that the end is not yet and that the end may be more glorious than the beginning. Only as one gets the feeling of the value and dignity of man in these terms is he apt to have a firm foundation for a democratic faith. Only as he sees man as a creature of unfathomed potentialities can he have intellectual justification for faith in sound methods of thought, in knowledge and understanding, in service to the community as worker and citizen—in the very things for which engineering education stands. History, properly taught, must be realistic in pointing out the failures of man, but its realism must include the ideas which will give the student hope and purpose for himself and for the society in which he lives.

Implications

From this discussion of the functions of history in engineering curricula certain implications arise which now should be made explicit. First, the course in history in the engineering school is not an independent unit existing for itself alone. It is or should be one part in a program which is designed to achieve definitely known objectives. The course will therefore probably be unlike that taken by liberal arts students whose interests are not the same and who may wish to major in the subject. But it need not necessarily be completely different. All students need many common elements in their training. The engineering student is going to be a citizen as well as an engineer. Nevertheless, his interests are different. Just as important is the fact that his curriculum diverges from that of the liberal arts student in classroom hours, in content, in the definiteness of the materials he uses, and in the amount of time available for the study of history and immediately allied subjects. The articulation of history with the rest of the curriculum is of especial importance.

Second, if history is to perform valuable functions in the engineering curriculum, a large measure of planning will be necessary. Objectives must be formulated and be familiar to all members of the teaching staff and others upon whose work the study of history impinges. As has been suggested, the formulation of objectives involves their determination in relationship to other courses. It involves further a specific statement of goals for the course itself. After all, students absorb and retain a limited amount from any one course. As far as history is concerned, the limitations are more severe in the teaching of engineering students, since unavoidably they must spend most of their time on other courses whose subject matter touches directly upon history only in slight degree. They do not, therefore, secure the reinforcement of ideas which comes to liberal arts students from constant contact with materials which may well have a bearing upon history. It follows that history teachers in engineering schools must become more and more specific about the methods, concepts, and knowledge which they hope the student will retain as a result of his contact with the study of history. They can hardly be satisfied with pious hopes that the student will gain some vague benefits from exposure to the subject. If they themselves do not know what history has

to offer, what useful ideas may arise therefrom, what guideposts to effective thinking it offers, then they can hardly expect that the undergraduate student will derive much benefit. The original, though not the sole, responsibility for making the course function as it should rests with the teachers, and any resemblance between the ideal and actual functions performed cannot be left to coincidence.

Third, carrying out the plan for the course will involve a rigid selection of materials. Obviously it is impossible to cover the whole field of history. No attempt should be made to do so. Once the objectives of the course are determined, the field of history should be combed to find the cultures, the periods, and the materials best suited to achieve those objectives. Many periods and much material traditionally covered must be eliminated. Any pangs of conscience which may result from that fact can be soothed if the new course has more point and achieves more effectively the known objectives. The aim should be not so much to cover the maximum amount of material as to insure that the student understands and can use effectively what is studied. If he acquires that skill, is familiar with the possibilities of the historical approach, and has developed an historical sense, he will be better equipped than if he merely remembers a miscellany of facts. Facts are important and out of them may arise attitudes, but they become most valuable only when they also contribute to sound thinking. The materials which are used might well be chosen with those criteria in mind. There should be an awareness of what is being included, of what is being omitted, and of why the selection was made.

Fourth, the course should be so designed that the purpose is clear at any particular point in it. Greater emphasis may be placed upon method of thought at one time than at another. That fact should be known to the teachers and certainly should become apparent to the students as the course proceeds. Later, the burden of the course may be the consideration of social values as a means of developing ideals and attitudes. Some other portion of the course may have as its special task the imparting of information which will lead to a greater understanding of modern society. Of course, these aims are not mutually exclusive, but the emphasis might well shift; in fact such shifts might occur from day to day. One class period might be devoted to collecting facts, a process which would be aimed partly at method and partly at knowledge and understanding. The following period might be devoted to drawing conclusions from these facts, a process which would be concerned at first with method, but which then might lead to use of those conclusions as a means of developing attitudes. The point is that both teacher and student should be aware of the emphasis so that the end of the exercise will bring a feeling of definite, measurable accomplishment.

Fifth, the history course will best perform its functions if it practices what it teaches. A certain amount may be learned from hearing and watching others; a great deal more will be learned from the actual doing. If one objective is to teach the student how to attack a problem, then problems must be attacked that way in class and the method followed through. If another objective is to help the student to learn how to use the inductive method, then he must be taught by that

method both in class and in his outside work. It is not enough to read materials which set forth the conclusions for him. In the classroom he must use the facts, not merely repeat them. In exercises outside of class, he must be held responsible for gathering reliable facts and for arriving at valid decisions under his own steam.

Finally, the instructor must possess knowledge and manifest an understanding of the problems with which he deals and of the students with whom he works. In so doing he may exemplify some of the social attitudes which the course should encourage and which should be a part of his own life and class procedure. Respect for the individual, belief in and use of the scientific method, faith in discussion—these should be incarnate in the course. The teaching of history in the engineering curriculum should be education and practice in good engineering, good citizenship, and satisfying personal living at one and the same time.

William P. Kimball has been appointed dean of the **Thayer School of Engineering at Dartmouth College.** Dean Kimball, who assumed his post in November 1, has been acting dean of the school for the past six months and before that was assistant dean under the late Frank Warren Garran.

A graduate of Dartmouth in the class of 1928, Dean Kimball received his Civil Engineer degree from the Thayer School in 1929 and taught there for one year before going to the Massachusetts Institute of Technology to do graduate work. In 1931 he joined the firm of Moran, Proctor, Freeman, and Meuser, consulting engineers in New York, and remained with them until he came back to the Thayer School in 1933. He has been a full professor of Civil Engineering there since 1939 and holds a Master of Arts degree from Dartmouth.

The U. S. Naval Postgraduate School

By CAPTAIN H. A. SPANAGEL

Head, Postgraduate School, U. S. Naval Academy

The Chief of Naval Personnel recently invited a group of nationally recognized engineering educators to visit the U. S. Naval Postgraduate School at Annapolis, Maryland, for the purpose of inquiring into the character and scope of instruction presented at the Postgraduate School. The group also considered the propriety of authorizing the award of Masters of Science and Doctors of Science Degrees to student officers who fulfill established requirements for these degrees. The educators who met at Annapolis with the Head of the Postgraduate School, Captain H. A. Spanagel, U. S. Navy were: President H. T. Heald (Ill. Inst. of Tech.), Dean Emeritus D. S. Kimball (Cornell), Dean W. B. Kouwenhoven (Johns Hopkins), Dr. R. S. McBride (E.C.P.D.), Dean E. L. Moreland (M.I.T.), Dean A. A. Potter (Purdue), and Dean H. M. Westergaard (Harvard).

During the meeting, the members of the group carefully analyzed the several curriculums; inquired into the details of instruction, and the quality of the students; examined the schedules of both students and instructors; and inspected the facilities of the Postgraduate School. The keen interest in the Navy's postgraduate training program displayed by these educators, and their constructive criticism will be of inestimable value in arranging the Navy's post-war plans for graduate education of its officers.

The Navy has long recognized the value of advanced technical education, with specialized training to meet specific Naval needs. The Postgraduate School was established at the Naval Academy for this purpose in 1909. The School has continued since that time, except for a brief period during World War I. It has grown from a small staff and a few students until the number of officers under graduate instruction now exceeds six hundred. The value of officers with specialized technical training has been fully proven. Many of the flag officers afloat, heads of technical bureaus, and key subordinates in those bureaus are former Postgraduate School students.

Officers for postgraduate training are selected from applicants of both the Regular Navy and the Naval Reserve who have shown particular aptitude in the various specialties. High standards of admission have been set for guidance in selection. A Bachelor of Science Degree from a recognized educational institution is a prime requisite.

All technical curriculums are designed as three-year educational programs to fulfill specific service requirements. In many of these curriculums the third year is spent in recognized civilian educational institutions. The following engineering curriculums are

established at the PG School: Aerological, Aeronautical, Electronics, Ordnance, and Naval (Marine) Engineering. Aeronautical Engineering is subdivided so that officers with special qualifications and talents may specialize in Power Plants, Structures or Armaments. Ordnance Engineering is further divided into General Ordnance, Explosives, Torpedoes, Metallurgy and Fire Control. Naval Engineering is a broad course embracing both Mechanical and Electrical Engineering. Recently, curriculums have been established under Naval Engineering, in Chemical Engineering and Petroleum Engineering.

In the interests of furthering the Navy's educational program, the Navy Department has granted authority to the Postgraduate School to participate in an exchange professorship program with selected colleges and universities. The warm response by civilian educational institutions to this plan assures its being made effective as soon as the country's educational system returns to peace-time schedules.

Streamline Graphics

By Major J. P. VIDOSIC, Director and Chief of Instruction
Army Air Force Engineering School, Wright Field

The slow, scarce airplane of yesterday was a taylor-made machine manufactured in custom-built shops. A national production of one hundred a year was rarely exceeded. Its construction by artisans skilled in the technique of smithing was therefore both appropriate and sufficient.

The body lines of the fuselage, empennage and canopy, for example, were laid to full scale on the floor of a large room set aside for this purpose. Shoeless draftsmen drew with long battens, bar compasses, splines and weights on painted wood or metal, developing the lines and contours of the complex geometrical shapes that make the airplane. This method of lofting was adopted from the shipbuilding industry, where the boat lines are laid down on the floor of the "loft" in which the frames and plating of the ship are fabricated.

When the requirement for large volume production was announced at the outbreak of the European conflict, alert aeronautical engineers quickly realized that the task could not be accomplished by slow loft room procedures. Mass production d i c t a t e s construction by methods that permit the manufacture of tools and parts at points remote from the source of information and assembly. Furthermore in order to reduce drag and gain speed, body contours must be exact, regular and undisturbed. A scientific approach based on graphical and mathematical processes therefore became e s s e n t i a l. "Necessity is the m o t h e r of invention" was rapidly proved true by a host of young engineers who tackled the problem enthusiastically. The science of streamline graphics was literally rushed through its infancy, childhood and adolescence and is now well along its path of maturity.

The fair-by-eye curve had to be, and was, replaced by mathematically definable curves that could be analyzed accurately. As a result the present day airplane is made up primarily of second degree or conic curves. The conic section is dictated by these advantages:

(1) Second degree curves form surfaces which are entirely satisfactory from an aerodynamic consideration.

(2) Second degree surfaces can be fabricated and assembled readily, accurately and economically.

(3) Second degree curves can be constructed graphically.

(4) Second degree curves can be defined and analyzed mathematically.

(5) Second degree surfaces have esthetic value (an important factor for post-war markets).

The basic principles upon which conic body drafting is based are not new. The theorems of Pascal and Brianchon form the basis for much of the graphical work. Analytic geometry as well as some elements of calculus are needed in mathematical analyses. An engineer prepared to handle the lines

lesign of streamline bodies must be ained in orthographic projection, geo-etrical construction, projective geom-try, analytic geometry, algebra, trigo-nometry and calculus.

It seems that somewhere between the d of courses in engineering draw-g and beginning of courses in design of streamlined machines there should be introduced an appropriate course in modern body drafting. This introduction should be accomplished in aeronautical, automotive and naval architecture curricula. Will the American engineering college meet this need? What do you think?

Necrology

The North Dakota Agricultural College records with deepest sorrow the death on July 4, 1945, of Harry Speer Rush, Professor and Head of the Department of Electrical Engineering. With his passing the college loses the services of an able and distinguished member of its staff and the engineering profession loses one whose life contributed significantly to the cause of engineering education.

Coming to the college in 1920, Professor Rush had at the time of his death just completed a full quarter of a century of exemplary service to the college. During that time he has left a lasting impress for good upon the department of which he was the head, upon the School of Engineering, and upon the entire institution. His colleagues had learned to value and respect his well considered opinions and judgments. Graduates and former students everywhere whom he had helped to qualify for positions of responsibility and consequently will long cherish the memory of Professor Rush for his fine character, for his sterling worth, and for his great competence in the field of electrical engineering.

BE IT THEREFORE RESOLVED that inasmuch as the North Dakota Agricultural College, the State, and this community; his colleagues, his friends, and his former students all have sustained a great loss in the passing of Professor Rush, this memorial be permanently recorded in the minutes of the College Council.

BE IT FURTHER RESOLVED that copies be sent to his family, to the American Institute of Electrical Engineers, to the Society for the Promotion of Engineering Education, and to the North Dakota Society of Professional Engineers.

A Humanistic-Social Overhauling

By CLEMENT J. FREUND

Dean, College of Engineering, University of Detroit

The engineer is a philistine. At least that is what thoughtful engineers tell each other whenever two or more of them get together. They call themselves uninformed, narrow, naive, unlettered, crude. Professor V. M. Faires complains of "lack of interest in if not complete ignorance of social, political and philosophical problems." * Mr. Owen D. Young believes that men working on scientific problems "get too specialized a view at the expense of a general capacity to organize and command large projects." † Mr. Herman Weckler, vice-president of the Chrsyler Corporation, explains that engineers never become executives in the automobile industry (or almost never; he is an engineer himself) because "They are afraid to think much ahead of the physical laws, and of the experimental data which they accumulate. The executive has to be more venturesome."

Perhaps they all exaggerate, but where there are vast clouds of smoke there must be at least a little fire.

A Revision Project

In 1939 the faculty in Engineering of the University of Detroit undertook to revise their whole program of non-technological courses in order, if possible, to rear young engineers who would be less "naive, unlettered, crude," who could not be called philistines. Right at the start they rejected the familiar proposition that the broad education of engineers is possible only by adding a year to the curriculum or by stealing time from technological courses. They hoped instead to accomplish their objective by improving the effectiveness of non-technological courses without, however, increasing the portion of time allotted to them.

A comprehensive report on the revision of general studies was made to the Council of the Faculty in June, 1941. The faculty strenuously debated the report in monthly meetings during the school year 1941–42. Late in 1942 a revised report was submitted, and the faculty adopted the final form of the report early in 1943. Thereafter, during the year 1943–44, the directors of curriculum departments began to reorganize their curricula in compliance with the report, and the entire project is now practically completed. Only minor changes in syllabi must still be made.

Aims of the Revised System of General Courses

Before they began actual work on this revision project, the faculty had to answer a fundamentally important

* "Post Graduation Education for Engineering Graduates," Journal of Engineering Education, Vol. 24, New Series, November, 1933, pp. 210–216.

† Quoted in "Engineers, Managers and Engineering Education," by W. E. Wickenden and Elliot D. Smith, Journal of Engineering Education, Vol. 22, June, 1932, p. 848.

question: What, precisely, were they trying to accomplish; what should be the purposes of a system of non-technological courses? It was a hard question. It apparently confounds even presidents, deans and professors in colleges of liberal arts. The faculty studied the aims for "humanistic-social studies" in the report of the Committee on Aims and Scope of Engineering Curricula of the Society for the Promotion of Engineering Education.* But they suspected that Dean Hammond and his able committee had in mind rather an aiming point or an ideal; the committee probably did not believe that every graduate of our colleges of engineering, or even a majority of them, could actually meet their specifications. In fact, an arts and science faculty would doubtless be elated if any besides a gifted minority of their graduates could reach these ideals.

With an eye to the ideals in the Hammond report, the University of Detroit faculty undertook to put together a new set of purposes to define what they might expect really to do, a set of purposes which they could display to engineering employers and to leaders in the profession and say, "These are our aims; we invite you to check any one of our graduates against them." After much thinking and talking and writing and rewriting again and again, the faculty finally adopted the following:

"1. A thorough understanding of a set of principles whereby the engineer may live and practice his profession so as to procure the greatest good for his fellow men, and accomplish his own basic purpose in life.

"2. Cognizance, if not expert understanding, of social conditions and developments, and particularly of the influence upon them of engeineers and engineering.

"3. Practical facility in written and spoken English; introduction to and at least some appreciation of specimens of the best in English literature."

Structure of Existing Offerings

The faculty next confronted the question: Do our present offerings of general courses accomplish these purposes? The following had been required of all engineering students:

Accounting (two courses)	4 credit hours
Business Law (one course)	2 credit hours
Economics (two courses)	3½ credit hours
English (four courses)	12 credit hours
Industrial History (one course)	2 credit hours
Industrial Organization (one course)	1⅓ credit hours
Religion, or Morality and Ethics (four courses)	8 credit hours
Total	32⅚ credit hours

Individually, as separate and distinct items, these courses could hardly be challenged. Each of them doubtless contributes to the new purposes. But the faculty could discover no evidence whatever, not in minutes of the faculty, not in minutes of the Council of the Faculty, nowhere, that these courses had ever been designed as a unified system. More probably they had been introduced piecemeal into the curricula by pressure from enthusiasts in the faculty or from influential alumni or employers, or by scheduling convenience, or by any and every procedure other than a judicious answer to the question: Just what are we trying to achieve by these general courses?

In the light of this question the fac-

* By H. P. Hammond et al. Journal of Engineering Education, Vol. 30, March, 1940, p. 564.

ulty examined in turn each of the established general courses. They decided as follows:

Economics

As might be expected, the faculty voted to retain instruction in economics because such instruction contributes, not casually or incidentally, but importantly to the adopted purpose of "Cognizance, if not expert understanding, of social conditions and developments. . . ." However, the faculty discarded the sequence of two economics courses in favor of a single new course, about which more in a moment.

English

The English courses should achieve the aim of "Practical facility in written and spoken English; introduction to and at least some appreciation of specimens of the best in English literature." In 1937 the faculty had completely overhauled the English courses and had specified two semesters of conventional rhetoric and composition, a semester of English literature and a semester of speech and of report and communication writing. They did not disturb this plan.

Religion, Morality-Ethics

Neither did the faculty disturb the sequence of four courses in religion or morality-ethics which had likewise been reconstructed in 1937 and which clearly serve to equip the student with "a set of principles whereby the engineer may live and practice his profession . . .", and to impart knowledge "of social conditions and developments. . . ."

Accounting, Business Law, Industrial History, Industrial Organization

These courses are all industrial in character. The faculty threshed them out most thoroughly, and their discussion disclosed that:

(a) This series of industrial courses comprises nine and one half credit hours out of a total of 32% for all required general courses in the curricula. But industry probably is not that large a proportion of the sum total of "social conditions and developments, and particularly . . . the influence upon them of engineers and engineering" as defined in the second of the new aims.

(b) Familiarity with industry will be an important by-product of the technological studies in the curricula.

As a result of their discussion, the faculty discarded all these courses from the regular curricula with the exception of a revised form of one course in accounting.

New Courses

Discarding courses, even when carefully and conscientiously done, is not too burdensome. (It partakes somewhat of the joyous character of window smashing and other destructive juvenile pastimes.) To construct a program of general courses to satisfy their new set of aims was an altogether different matter, as the faculty soon discovered. They persevered, however, and after endless months of labor, of sharp disagreement and adroitly contrived compromise, they approved the following system of non-technological courses for the upper divisions of the curricula, with objectives as indicated:

Economics

"To impart an understanding of the principles of production, distribution

and consumption of wealth, and of the importance of these activities in the life of the community."

Industrial Accounting

"To impart an understanding of how and to what extent engineering undertakings depend upon economic considerations and of the methods whereby the economic aspects of engineering undertakings are controlled; to impart a full appreciation of the elements which constitute cost in engineering undertakings."

Sociology

"To impart an understanding of social problems, particularly of current problems and of those which are related to engineering and industry, and of correct principles and feasible means for the solution of these problems."

Personnel Relations

"To impart an understanding of principles and policies, and information concerning procedures for the adjustment to their positions and tasks of industrial employees, including professional, technical and supervisory personnel as well as workingmen and women."

History of Engineering

"To impart an understanding of the development of the engineering profession as a vocational group in society, and of the changes which have been brought about by applied science in manufacturing, mining, agriculture, transportation, communication, and in local and national government and administration."

The Profession of Engineering

"To inform students concerning careers and opportunities, movements and trends in the profession, codes of professional ethics, and the status of engineers in the community."

The Industrial Options

All senior students may elect an industrial option, except students of chemical engineering who may choose a corresponding option in metallurgy. For these industrial options the faculty adopted two courses which had been eliminated from the regular curricula:

Industrial Organization, First Semester

"To impart an understanding of principles and trends which have strongly influenced the institution, development and operation of industrial enterprises; likewise, to impart information concerning the techniques for the organization and operation of industrial enterprises."

Industrial Organization, Second Semester

"To impart an understanding of principles and trends, etc., continued, with particular reference to the organization and operation of manufacturing enterprises."

In addition, the faculty introduced two entirely new courses into the industrial options:

Cost Accounting

"To give a thorough training in the principles and methods of ascertaining costs of engineering products."

Industrial Economics

"To impart an understanding of principles and techniques for the economic and financial analysis of engineering projects; this analysis to parallel the technical analysis and comparison. This course should instruct the student in the method of

determining the economic feasibility of engineering undertakings."

Arrangement

The assignment of the new courses to semesters was much easier than had been expected. The average engineering student has a decided vocational attitude; he is inclined to belittle any course which does not seem clearly to prepare him for his life work. The faculty, therefore, included at least one general study in each semester in order to impress upon the student the professional significance of such studies. And since the student will obviously encounter a succession of both technological and human or social problems all his life, the faculty thought it logical to confront him with just such a combination throughout his college career.

A course in English and one of the religion, morality-ethics group have traditionally been assigned to each freshman and sophmore semester. The faculty left them there as most students who withdraw from college do so in the first two years, and these courses are clearly valuable in all walks of life. Similarly, economics and the related course in accounting have wide application within and without the engineering profession. Sociology and personnel relations apply almost as widely, while the history of engineering and the profession of engineering primarily concern engineers. Accordingly, the faculty arranged the courses as follows:

Freshman—First Semester
- English
- Religion or Natural Religion

Freshman—Second Semester
- English
- Religion or Morality

Sophomore—First Semester
- English
- Religion or Ethics

Sophomore—Second Semester
- English
- Religion or Ethics

Junior—First Semester
- Economics

Junior—Second Semester
- Industrial Accounting

Pre-Senior—First Semester *
- Sociology

Pre-Senior—Second Semester *
- Personnel Relations

Senior—First Semester
- History of Engineering

Senior—Second Semester
- Profession of Engineering

Senior, Industrial Option—First Semester
- History of Engineering
- Industrial Organization
- Cost Accounting

Senior, Industrial Option—Second Semester
- Profession of Engineering
- Industrial Organization
- Industrial Economics

Conclusion

An unexpected and altogether beneficial by-product of the revision project was the reorganization of a number of strictly engineering courses. Directors of certain engineering departments had been thinking and talking for some time about revising their technological courses, but had not got to work because of the burden of current duties, especially war tasks, and other reasons. However, they quickly rebuilt their courses when they found that they had to shift them in any case in order to adjust them to the new structure of general studies.

The faculty have not been deluded. They do not believe that this revision

* Engineering curricula in the University of Detroit are on a five year, cooperative basis.

is by any means the final and complete answer to the problem of the broad education of engineering students. It is possible, indeed, that no single and comprehensive solution will ever be evolved. But they do contend that the new studies are a decided improvement over the haphazard, disconnected offerings to which students are subjected in too many colleges of engineering; and they contend that the new curricula impart a reasonably complete general education. It must not be forgotten that scientific and technological studies have a distinct cultural value, particularly in this mechanical age, as President Harvey Davis, Dean A. A. Potter and others have reminded us again and again.

Under the new plan, all students must complete the following scientific and cultural courses:

English (four courses)	12 credit hours
Religion, Morality-Ethics (four courses)	8 credit hours
Chemistry (two courses)	8 credit hours
Physics (two courses)	10 credit hours
Mathematics (four courses)	18 credit hours
Economics (one course)	2 credit hours
Sociology (one course)	2⅔ credit hours
Total	60⅔ credit hours

These courses obviously are not the equivalent of a comprehensive liberal education. But they doubtless are the equivalent, for the purpose of liberal education, of the usual 64 to 68 credit hour, pre-professional curriculum in colleges of arts and sciences. And certainly the new program is much more nearly a true liberal education than the uncoordinated assortment of majors, minors, free electives and odds and ends for which a bachelor's degree is granted in many an American college.

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Training for Thinking—Or Mass Production of Robots?

By L. M. DURYEE
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Ten men sat in conference. All were graduate engineers and members of the teaching profession in the electrical department of the college. The engineering curriculum was under review. The subject for debate: Shall we give mechanics of materials in sophomore year or in junior year? It was an extremely serious discussion.

I open this article with this description because in this country we have reached a turning point in education which is going to profoundly affect our lives and our businesses. It is not a question of whether we teach mechanics of materials in second or third year. This serious debate described above is simply symbolic. The real question is: shall we bend our efforts to train men as human beings, capable of taking their places of leadership in our industry and in our government, or are we merely going to concentrate still further on scientific training—with all that it entails—and turn out prefabricated scientific automatons?

The subject assumes special significance as we view the international horizon. On the eve of the birth of a unity of nations, we also look upon a social upheaval in Europe and in England. We see that scientific advancement has wrought much havoc in the world, and that the aftermath of this avalanche leaves chaos in many places, and in the minds of many people, both abroad and here at home.

The question which must be answered by the responsible members of the engineering fraternity is this. Will this chaos and social unrest be best solved by a new generation of Americans trained *more* in the sciences, *less* in the humanities. Will mechanics of materials do more for our new crop of leaders than a course in modern history? Will a program of electronic therapy develop leadership and human understanding better than an education in foreign languages or in the world's regions? Will our problems of industrial management be solved by men versed in hyperbolic functions, or by men familiar with literature and humanities, and with the struggle of people throughout the ages? Above all, isn't an ability to express one's self in good English of greater value than a complete mastery of integral calculus?

Too much specialization in engineering curricula can be even more dangerous, in the future, than it was in the past. In past years the leavening effect of broad high school studies developed somewhat broader viewpoints. Contrast this with the vocational training in many of the public schools today. Now, following a limited pre-engineering training in high school, many students are hurried through an accel-

erated program of mechanics and electronics. Liberal arts colleges, formerly open to the high school graduate, are now closed, due to military necessity. Because of the scientific war we fight today, great stress is laid upon engineering. But we must remember that Hitler took over Germany's future by eliminating all German culture from the educational program of the country. We have also done this. In its place Hitler substituted a training in technique, in production, in jet propulsion, and in scientific development. When he later rose up among his countrymen and proclaimed himself as Fuehrer, the people hailed him as their God. His distatorship was supreme because in a totalitarian state citizens should not think—and they didn't.

Never in the history of the world has purely scientific training developed leadership, human sympathy, or sound thinking. The influence of training is unquestionably the greatest by which people reach their final goal.

The importance of the selection of proper teachers has only lately been given the attention of industrial leaders which it so justly deserves. Teachers in scientific schools should be especially well selected, because of the de-humanizing influence which scientific study exerts. The engineering instructor should be a human being first, and a trained technician second. We think of Dr. Pupin, of telephone fame, as a great engineer, but there was a time in his life when he had to be assisted in his efforts to eat. To talk. To walk. How his mind developed beyond that depended upon further teaching. The art of teaching in America is not lost, but the recognition of its importance is almost forgotten.

Today it must be conceded that the desire for vocational training takes precedence over everything else. President Hutchins of Chicago has said that colleges today go so far in the direction of "training for making a living" that one western university even offers a full college degree in the science of Cosmetology. Thus the 1945 Beauty Technician now takes his place beside the Bachelor of Arts and the graduate engineer as a fully educated man.

The counter-balancing effect of humanizing young Americans can come only through revised curriculum and all around excellence of teachers. The influence of a properly selected instructor can be sufficiently great, even within the confines of electrical laboratory classes, that students will realize that "making a living" is not the sole end of education. Too many engineers make a living, but never learn how to live with their fellow men.

President Doherty of Carnegie Tech recognized the seriousness of the situation long before the humanizing effects in education were drastically reduced, when the closing of all liberal arts colleges took place at the time of the Pearl Harbor disaster. He said:

"There must be a clarification of basic philosophies, personal, professional, social. There must be clear, straight thinking. To have this we must have genuinely educated people. Walking handbooks will accomplish little. Graduates who have learned only the routine skills will be intellectually lost in a world of new problems. There must be an intellectual renaissance. This is your challenge."

Walter Lippman, who has no personal axe to grind, describes contemporary education in these words:

"There is no common faith, no common body of principles, no common moral and intellectual discipline. Yet the graduates of these modern schools are expected to

form a civilized community. They are expected to govern themselves. They are expected to have a social conscience. They are expected to arrive by discussion at common purposes. When one realizes that they have no common culture, is it astounding that they have no common purpose? That they worship false gods? That only in war do they unite? That in the fierce struggle for existence they are tearing western society apart?"

The goal of all education should be to produce graduates who think. Industrialists who have interested themselves in education—and the list is growing—are unanimous in their plea that fundamentals are important. They do not want technical specialization to hamper the student's ability to think along lines of human engineering. They insist that the specialized training can be taught later, in the particular industry represented. And in this respect, these industrialists are in reality pleading for an education which fits people for Freedom.

The best that can be said for Education for Freedom has been written by a wounded G.I. who spent fifteen months in the Mediterranean theater. Corporal Zurossky wrote the Army's prize-winning paper from a veterans' hospital. The subject "Why I Fight".

"I fight because it's my fight.

I fight because my eyes are unafraid to look into other eyes. Because they have seen happiness and because they have seen suffering. Because they are curious, and searching. Because they are free. But if I *see* and do not *think*, I am blind.

I fight because my ears can hear both sides of a question. But if I *hear* and do not *think*, I am deaf.

I fight because my knees bend only to God.

I fight because of all these. And because I have a mind, a mind which has been trained in a free school to accept or reject, to ponder and to weigh—a mind which knows the flowing stream of thought, not the stagnant swamp of blind obedience. A mind schooled to think for itself, to be curious, skeptical, to analyze, to formulate and express its opinions; a mind capable of digesting the intellectual food it receives from a free press. Because if a mind does not *think* it's the brain of a slave."

The group of ten electrical instructors who debated whether the mechanics course belonged in second or third year voted unanimously. When the conference ended the course in mechanics had been completely replaced with an entire year of electives in English expression: composition, extemporaneous and public speaking, for electrical engineering students. A start had been made. Educational experience which develops the ability to communicate, as well as to think, is one of the means by which the threat of the educated Robot can be effectively obliterated.

That the interest of community and business leaders is sorely needed in this program to stimulate sound thinking, no one will deny. It is forcibly illustrated by the recent report of Mr. Walter D. Fuller, Chairman of the National Manufacturers Association's Committee on Cooperation with Education. Mr. Fuller, in reporting on the 1944 activities of this nation-wide group, said: "We have taken a long step toward mutual understanding with education, but it is not possible to go the full distance in so short a time. The work has been too long neglected, so that today the responsibility is real; the need imperative; the situation acute."

It is obvious to any interested observer, after viewing the situation reported by Mr. Fuller and other indus-

trial and educational leaders, that the very survival of the American Way may be at stake. Every local community organization which participates in these thought-provoking industry-education meetings contributes its important share to America's future. And not the least of the subjects on the agenda of these meetings should be the raising of the economic status of the entire teaching profession. Only in this way can the more successful personalities be induced to enter the classroom. And only with stimulation from men of vision can we substitute an Education for thinking in place of our present trend toward production of Robots.

At the 1945 Annual Meeting of the **Engineers' Council for Professional Development,** October 19 and 20, Everett S. Lee, engineer of the General Engineering and Consulting Laboratory, General Electric Company, was reelected chairman and James W. Parker, president, general manager, and director, The Detroit Edison Company, Detroit, Mich., was reelected Vice-Chairman. Wm. N. Carey, Secretary and Executive Officer of the A.S.C.E., and H. H. Henline, National Secretary, A.I.E.E., were elected Secretary and Assistant Secretary, respectively.

For chairmen of committees: Committee on Student Selection and Guidance, Carl J. Eckhardt, Jr., Professor of Mechanical Engineering and Superintendent of Utilities, University of Texas; Committee on Engineering Schools, D. B. Prentice, President, Rose Polytechnic Institute; Committee on Professional Training, C. A. Pohl, consulting engineer, New York; Committee on Professional Recognition, N. W. Dougherty, Dean of Engineering, University of Tennessee.

The Best and Worst Teachers of Engineering

By H. H. REMMERS, K. S. DAVENPORT, AND A. A. POTTER
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Widely accepted and readily available criteria of teacher qualities related to good teaching are not now at hand; what is available are the judgments of those who underwent the teaching of specific individual teachers. The purpose of this study, the results of which are synopsized here, was to obtain some light on the dimensions of the characteristics of teachers of engineering.

A sample of more than 2,500 engineers was picked at random from the membership of the five leading engineering organizations—American Institute of Chemical Engineers, American Institute of Electrical Engineers, American Institute of Mining and Metallurgical Engineers, American Society of Civil Engineers, and American Society of Mechanical Engineers. These engineers were asked to rate each their best and worst teacher of engineering on the Purdue Rating Scale for Instructors, a graphic scale which rates the instructor on ten traits on a graphic scale of 0 to 100. Nearly 600 usable scales were returned, and any sampling bias which might have arisen because of the greater amount of interest and more pronounced views is probably to the good. Table I gives the ten traits, the mean rating of the best teachers, the mean rating of the worst teachers, and the difference between the means.

The returned scales were kept separate by the organization to which the engineer belonged, until it was found that there were no differences other than those which could be accounted for by chance alone between the mean scores for any trait and any organization; then all ratings were combined to make the groups given in Table I.

From Table I it is apparent that there is little resemblance between these two groups of teachers. On only one trait—9 (personal appearance)—does the group of worst teachers even approach the best teacher group, and this difference is far better than the one per cent level of confidence. It should be noted that the differences between the best- and worst-teacher means on traits 5 and 10—presentation of subject matter and stimulating intellectual curiosity—are greater than one-half the total possible range.

Since the mean best teacher of each organization possesses very nearly the same amount of the quality being rated on each trait, and this amount, while varying from trait to trait, maintains very nearly the same relative rank (in the ten traits) in each organization, and since the same statement holds true for the mean-worst teacher, it thus seems likely that there is a hierarchy of trait values for all teachers of engineering. Stevens* studied teachers of plant science and found

* Stevens, Neil E. "What It Takes to Teach the Plant Sciences," *Journal of American Society of Agronomy*, Vol. 36, No. 4, April, 1944, pp. 316–323.

TABLE I

TRAITS RATED, MEANS OF TEACHER GROUPS, AND DIFFERENCE BETWEEN MEANS

Trait	"Best" Mean	"Worst" Mean	Difference
1. Interest in subject	88.6	55.8	32.8
2. Sympathetic attitude toward students	83.4	43.8	39.6
3. Fairness in grading	87.6	59.6	28.0
4. Liberal and progressive attitude	82.4	40.2	42.2
5. Presentation of subject matter	88.8	30.4	58.4
6. Sense of proportion and humor	79.8	33.1	46.7
7. Self-reliance and confidence	86.8	50.7	36.1
8. Personal peculiarities	77.5	42.6	34.9
9. Personal appearance	81.7	64.2	17.5
10. Stimulating intellectual curiosity	87.1	27.7	59.4
Number	558	538	

similar rank and size of means for his teachers; consequently, a tentative hypothesis is advanced that the comparative rank of each of the ten traits would be virtually identical for any unselected group of teachers for a single university or from a number of universities.

Stevens posited the hypothesis that the size of the mean of the best teacher was an indication of the importance of the trait. He did not test this hypothesis in any other than in an a priori manner. In the original study † is reported the judgments of college students as to the relative importance of each of the ten traits. The rank-order correlation between this order of importance and the rank of the size of the mean in Stevens' study is +.82, in the present study it is +.92. Stevens, then, may well be right in his assumption.

The best teacher in engineering, then, is a teacher who is distinguished from his less able colleagues in that he has a much greater interest in the subject taught, that he is very able in the presentation of the subject matter, and that he can, to an unusual degree, stimulate the intellectual curiosity of his students. The worst teacher of engineering has also an interest in his subject, but lacks ability to stimulate the intellectual curiosity of his students and does not present the subject matter of the course in a satisfactory fashion. The size of the mean of the best and the worst teacher can provide a sort of a floor and a ceiling by which teachers within an institution can be measured.

A great many letters accompanied the returned rating scales, or gave reasons why the scales were not filled out. The ratio of favorable to adverse criticism was 15 to 1. A single comment from each position will illustrate the letters: "Many of my associates have voiced approval of your program and have expressed the wish that their schools might do the same. You are to be congratulated in carrying forward this program." "Sorry I cannot aid in what I would term a sort of

† Remmers, H. H. "The College Professor as the Student Sees Him," *Studies in Higher Education XI*, Division of Educational Reference, Purdue University, Lafayette, Indiana, 1929. 63 pp.

academic project of questionable value."

In the letter which accompanied the rating scales the names of the teachers who were being rated were asked. The writers do not believe that they will violate any confidences if the three teachers who were most often rated best are named here. They are D. D. Ewing, Professor of Electrical Engineering, Purdue University; Charles E. Gus, Professor of Engineering Mechanics, New York University; and Baldwin M. Woods, Director of University Extension, University of California.

The State University of Iowa. A summer hydraulic laboratory has recently been organized under the laws of the State of Colorado, with the name Rocky Mountain Hydraulic Laboratory. An excellent site on the North St. Vrain Creek, near Allenspark, Colorado, has been acquired as the first step in readying facilities for the engineers, hydraulics teachers, and students who may wish to spend their summer vacations working on some of the fundamental problems which are in need of experimental solution or verification. The site is near the Rocky Mountain National Park, and several hotels and a variety of rental cabins are available within walking distance. Discharge of the creek is many times that ordinarily used in hydraulic experiments, and it has nearly eighty feet of fall in the quarter of mile of length within the 20-acre site. All of the water diverted will be returned to the stream so as not to interfere with established water rights.

Use of the Laboratory's facilities will be open, upon registration and payment of fees, to all qualified persons. It is expected that the charges can be kept quite low, for there will be no pumping costs, and only a minimum amount of housing is necessary since the dry summer climate is ideal for outside work. The Laboratory will not grant academic credit nor certify to attainments, but individual staff members are at liberty to do so on their own responsibility. The staff for the summer of 1946 has not yet been announced.

Post-War Training for Signal Corps Reserve Officers*

By CLINTON W. JANES and JAMES O. SWEENY

Army Service Forces, Fort Monmouth, N. J.

How can we integrate a universal military training program with a college education in a maner which will both satisfy our national defense needs and benefit the educational institutions? Because of recently expressed opposition to the proposed military training program by the nation's educators, this question, long a topic of debate, has now risen to a critical priority among the problems facing America's military planners. Some educators have objected that the year of military training will lower the nation's educational standards by decreasing the enrollment in colleges and universities.

The experience of the Signal Corps and other technical arms and services during this war has shown the advisability of maintaining a sizeable reserve of adequately trained and technically qualified officer personnel. The largest potential source for this reserve will most likely be the engineering students of our colleges and universities. If a universal military training plan can be devised which will help fulfill the mission of both educators and military leaders, which will aid and not limit the flow of students to our educational institutions, and which will provide well prepared men for the national defense, it should be acceptable to both military and educational thought of the country.

The following plan is proposed as one solution to this problem. Specifically, the purpose of this plan is threefold:

a. To provide the Signal Corps with a constant and a predetermined input of electrical engineers who have specialized officer training in Signal Corps communication subjects.

b. To increase college enrollment by providing financial assistance to qualified engineering students.

c. To assist both education and industry by increasing the student's interest in his academic work and by providing him with practical operating experience of typical radio, telephone, and telegraph systems and facilities.

In order to put this plan into operation, it will first be necessary to determine which high school graduates intend to pursue a course in electrical engineering. Assuming that this can be done, the plan could operate in the following manner.

The one year period of universal military training will be divided into four lesser periods of three months each; the first stage of this training to

* The thoughts set forth in this article should not be considered to reflect present War Department doctrine or policies, and represent only the authors' opinions of a method of converting the so-called "lost year" of military training to a "gained year."

occur during the summer months between high school graduation and enrollment in college, and the second, third, and fourth stages to take place during the summer intervals between each college year.

During the first three month period, the prospective college student who has previously expressed a desire to enter an engineering course will be enrolled in the Enlisted Reserve Corps and will be given three months of basic training. This training will be substantially the same as the basic training program given to enlisted men during this war. The Enlisted Reservist will be paid by the government at the same rate of pay as a basic private. A definite effort will be made during this phase of training to "sell" the student on communications. This may be accomplished by several days of inspection of actual Signal facilities, set up and operating under simulated combat conditions. A student, at this time, will be shown the equipment with which he will be expected to work during the second summer period.

During the three months following his freshman year in college, the Enlisted Reservist, who will then have completed nine months of college training in general subjects, will participate in actual maneuvers, performing the duties of such assignments as Radio Operator, Telephone Operator, Teletype Operator, Lineman, etc. He will be eligible during this period for promotion to the relative grade of corporal.

During the third summer period, between his sophomore and junior years of college, the Enlisted Reservist will be trained in the elementary phases of at least one technical specialty such as Radio Repairman; Wire Chief, Central Office; Powerman; Central Office Repairman; Installer-Repairman, Telephone and Telegraph; and Teletypewriter Mechanic. During the latter part of the summer he will actually perform the duties of the position for which he has been trained and will be eligible for promotion to the relative grade of sergeant and staff sergeant.

In the final summer period between his junior and senior college years the Enlisted Reservist will complete specialist training in radio or wire subjects and will be eligible for promotion to the relative grade of technical sergeant and master sergeant. This fourth phase will also be utilized for training in customs of the service and duties and responsibilities of an officer.

Throughout these summer periods the Enlisted Reservist will be paid for the relative grade which he holds, in addition possibly to government financial assistance in the form of tuition furnished for his college education. Upon graduation from his senior year of college he will, if physically and technically qualified, receive a commission as 2d Lieutenant, Signal Corps Reserve.

It is proposed that the Enlisted Reservist, in addition to this summer training, will also participate in an R. O. T. C. program during his academic years. If the four phases of military training and the R. O. T. C. program are closely integrated, both in subject and teaching personnel, the electrical engineering graduate should be well qualified technically and militarily to perform the duties of a commissioned officer.

Programs similar to this might be designed to meet the needs of other technical arms and services such as the Chemical Warfare Service, the Ordnance Department, and the Corps of Engineers.

By the adoption of such a program, the authors believe, the so-called "lost year" could actually be a "gained year" to the advantage of the students, the educational institutions, American industry, and national defense.

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The Quest of knowledge

By B. HOWLAND
Washington, D. C.

At the start of the laboratory period there was the usual talk of going home. This was subdued by the instructor's customary reply, "You know I would like to go home too, but I don't make the rules." After a preliminary discussion of what was to be asked on the next test, how many days until vacation, and what was the absolute deadline for last week's lab report, the purpose of the day's experiment was announced: "The job for today is to measure the efficiency of a transformer. You will measure Z_1 Z_2, ... You can then check your value of efficiency by the A.I.E.E. formula on page 364 and the two should check within 0.2%."

The group started by wheeling approximately 800 pounds of transformers, inductances and resistors to a corner of the laboratory. For the next 15 minutes they mechanically connected up a table and checked out meters until it became apparent that they could no longer put off reading the mimeographed sheet, issued by the instructor to explain the experiment. After finding out what Z_1, Z_2, . . ., Z_m in the formula of page 364 stood for, the group was ready to begin.

With smooth efficiency they measured the D.C. resistances of the coils as they had done 231 times before, measured the A.C. impedance of the coils as they had done 173 times before, and recorded the nameplate data and meter numbers which were never used. Proceeding boldly with nothing to guide them but the data from a group that performed the same experiment last semester, they found Z_1, Z_2, . . ., Z_m.

The instructor meanwhile was going from group to group discussing the more theoretical aspects of the experiment. "What did you get for Z_4 of this transformer?"

"37.1 ohms."

"That's a little high, they averaged around 35 ohms." Subsequent measurements revealed the impedance to be more nearly 35.1 ohms.

The measurements were soon finished and the equipment was quickly dismantled—this making it impossible to check the data in case of an error showing up later. The group went to a quiet room where study would be facilitated by cigarettes and swing music. Six more columns of figures were computed as specified by the mimeographed sheet, two of which were later found useful in computing the efficiency. (By multiplying column 1 by column 2, dividing by column 3, and finding an angle that had this as a cosine, column 4 was obtained.) The final tabulations gave an efficiency of 98.1%.

The atmosphere was tense as figures were placed into the A.I.E.E. formula on page 364, yielding an efficiency of

98.6%, outside the tolerance. Subsequent calculations with the same figures gave the much more reasonable value of 98.2%.

All that was now necessary was the signature on the data sheet of the instructor who, fortunately, did not embarrass them with a question about where the A.I.E.E. formula came from (it came from page 364).

Physics Column

The following significant news item has been received from L. R. Ingersoll, Chairman, Department of Physics, University of Wisconsin: "The Faculty of the College of Engineering of the University of Wisconsin is considering a proposal of the Department of Physics to the effect that engineering students in any line, i.e., civil, mechanical, etc., be given the opportunity to secure what is effectively a minor in physics by adding sixteen credits of work in physics to the ten credits of general physics which all engineering students have to take. If this plan goes into effect, it will begin with the fall term of 1946."

This way of making available to industry technical talent with the increased conversance with physics which has recently proven so valuable, deserves serious consideration by many institutions.

A correspondent urges discussion of "the desirability of introducing vector analysis much earlier than is customary —possibly in general physics courses but at least in intermediate courses in mechanics and electricity." This advance is long past due. Can the mathematics departments assist?

Physics departments are reporting a gratifying return of staff members from war assignments. They are being warmly received since student loads are increasing proportionately.

JAMES G. POTTER,
Chairman, Division of Physics

Shrivenham American University

Shrivenham, Eng.—Going a long way toward making Shrivenham American University a "national college," the S.A.U. engineering instructors represent more than 14 engineering schools in the U. S. Nearly five hundred students are studying engineering subjects at the full-time army Information and Education division school in England, where the faculty includes:

(First row, l. to r.): Major Harold J. Monk, Tennessee Polytechnic Institute; Glen N. Cox, Louisiana State University; Daisell M. Grimith, Bucknell; Section Chief Robert F. Edgar, University of Pittsburgh; Major Charles O. Dawson, University of New Hampshire; Frank M. Theroux, Michigan State; John A. Weishampel, University of Alabama.

(Standing, second row, l. to r.): Fred J. Evans, Carnegie Tech; A. A. K. Booth, University of Connecticut; William J. Stevens, Drexel Institute; Captain Robert A. Gardner, Bucknell; William Schuller, University of Michigan graduate; Captain Lloyd B. Ritchey, University of Illinois.

(Standing, third row, l. to r.): Captain William J. Judson, University of Detroit; Elgin R. Wilcox, University of Washington; George M. Porter, Carnegie Tech; Major W. Irwin Short, University of Pittsburgh; Lt. William Long, University of Wyo-

Developing Creative Engineers*

By J. F. YOUNG

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To stimulate the development of creative, inventive ability in young engineers and to promote application of this ability in engineering, the General Electric Company eight years ago established its "Creative Engineering Program" as a partner to its well-known Advanced Course in Engineering. This paper reviews the progress made in understanding the rare talent of ingenuity, and also describes the selection of candidates, the training given, and the value of the program as indicated by the work of its "graduates."

For many years, industry has recognized the importance of creative, inventive engineering to continued progress and, accordingly, has accepted responsibility for the development of creative ability in young engineers. Usually, this has taken the form of the time-proved method of apprenticeship. Young men who show signs of creative talent are associated with senior engineers who can in some measure nurture its development and provide inspiration and guidance.

But even though management is ever on the lookout for men possessing this ability, their discovery in the past has for the most part been happenstance. It has usually been necessary for the creative spark to assert itself under conditions which did not encourage creative work or give opportunity for its practice. Sometimes, regular assignments have catalogued a man according to type, *e.g.*, research, analytical, or production, and the assumption of responsibility for a major project requiring broad creative ability and practical design sense might not be entrusted to him. Under these circumstances, only exceptional men gained recognition for creative genius, and the intuitive abilities of countless engineers have been lost to industry and to society.

Program Organized

In the interest of establishing a more purposeful plan for discovering and developing these abilities, particularly in young engineers, the author's company, in 1937, organized its "Creative Engineering Program," under the able direction of Dr. A. R. Stevenson, Jr., director and co-founder of the company's already famous Advanced Course in Engineering.† This paper outlines some of the factors associated with a creative approach to engineering problems and shows how these factors apply to the selection of personnel and to the training given in the new program.

When the program was begun, creative capacity was initially interpreted

* Reprinted from Dec. 1945 *Mechanical Engineer.*

† "An Advanced Course in Engineering," by A. R. Stevenson, Jr., and Alan Howard, *Electrical Engineering*, Vol. 54, 1935, pp. 265–266.

(First row, l. to r.): Major Harold J. Monk, Tennessee Polytechnic Institute; Glen N. Cox, Louisiana State University; Daniel M. Grimsh, Bucknell; Section Chief Robert F. Earp, (Standing, third row, l. to r.): Captain William J. Judson, University of Detroit; Elgin R. Wilcox, University of Washington; George M. Porter, Carnegie Tech; Major W. Irwin Short, University of Pittsburgh; Lt. William Lang, University of Wyo-

as facility in the art of design; * that is, the emphasis was placed on ingenuity for selecting materials and functional-design forms and adapting them to manufacturing processes. This type of activity is within the field of mechanical engineering, so only mechanical graduates interested in design work were selected for the first classes. For an industry which manufactures many electrical products, such a procedure might, at first seem restrictive. But, design or production of even electrical products like induction motors or radios involves from 70 to 80 per cent mechanical engineering, and it, therefore, seemed reasonable to start with this phase alone.

It soon became clear that emphasis on the art of design was adequate for "reduction-to-practice" engineering but overlooked the imaginative, creative engineering that goes into the choice of the fundamental design plan. The guiding objective was, therefore, enlarged at the end of the second year to interpret creative engineering in a broader sense as comprising the entire chain of efforts leading from the conception of a device to its delivery to the customer. This meant that invention in the elements of a device or its final form was an essential but component part of the creative process. It also meant engineers with electrical or electronic interests, among others, should participate. The program is still organized on this basis.

Men possessing the talent sought were not easily selected at the outset. Upon contacting college professors concerning students who might have the proper aptitudes, the answer was usually the same, "We do not know. There is nothing in the college curriculum to show us." This condition is slowly being altered and a greater emphasis placed on the artistic, creative side of engineering in the colleges and universities as a result of encouragement by industry and the engineering societies, particularly the A. S. M. E. through its Committee on Education for the Industries.†

The Technique of Synthesis

The failure of formal study to bring out creative talent is probably best explained by the contrast between the method of analysis which underlies scientific training and the method of synthesis employed in the intuitive process of invention. The analytical method is habitual, logical, step-by-step. It involves critical separation of each element of a system and discovery of interrelationships. Through this method, as applied to design, optimum refinement and improvement are often accomplished, but, strictly speaking nothing is created. The results of analysis may, however, establish the requirements leading to invention. For example, calculations on ballistics may suggest requirements for a bomb sight or a gun director; but a new choice of elements to perform such a function or an idea of some new function is an act of synthesis apart from the analysis. In accomplishing the act of synthesis, it is necessary to obtain an approach to the problem that is not habitual from the stand point of current practice. New, unprecedented association or combination of similar, contrasting, or succeeding elements is arrived at. The form of product undergoes development and functional arrangement rather than introspection. In these re-

* "Encouraging Creative Ability," by A. R. Stevenson, Jr., and J. E. Ryan, *Mechanical Engineering*, Vol. 62, 1940, pp. 673–674.

† "Creative Engineering," A. S. M. E. July, 1944.

spects, synthesis is not acquired by scientific training but must survive this training and instinctively apply its technique.

Normally, there can be no constructive synthesis without a proper understanding of the underlying fundamentals. In any creative endeavor, analysis and synthesis must go along together, supporting each other. When one man does not possess these abilities in the measure required, the complementary talent, together with the others * usually needed, are provided by teamwork.

Experience with young engineers doing creative work indicates that the process of synthesis is essentially individualistic. The techniques used differ considerably and, thus, are not amendable to "teaching." Perhaps this is a further reason that creative ability does not flourish under formal study. Within the techniques of synthesis observed, however, there appear to be four † common stages. In so far as recognition of these stages can make the young engineer aware and confident of the progress of his creative effort, they are presented as an acceptable structure for promoting the application of these abilities to engineering problems.

1. *Definition of the Problem.*—Before any suitable action can be taken, the problem must be found and formulated. It is highly important that the problem be defined exactly, and sometimes data must be gathered for this purpose. Most people are not inventive because they do not take this step, or because they become discouraged with initial failures; others because they define the problem erroneously. Inexact definition may result from influence of the past art (that is, not getting a non-habitual approach), or from insufficient understanding of the fundamentals involved. The result in either case is solution of the wrong problem. For example, the first alternating-current contactors for breaking a resistance-load current opened as fast as possible because this had been found necessary for earlier designs of direct-current contactors. Actually, less contact burning is obtained by breaking this type of load slowly and extinguishing the small arc as the alternating-current voltage goes through zero, rather than by fast opening, which draws a large hot arc, and depends upon extinguishing the arc by air cooling.

2. *Manipulation of Elements Bearing on Solution.*—In this stage, indi-

* "How Collective Genius Contributes to Industrial Progress," by K. K. Paluev, *General Electric Review*, Vol. 44, 1941, pp. 254–261, points out that some 15 basic faculties are important to the creative process. Later analysis indicates these may be further subdivided into 36 elements, 2 physical, 4 intelligence, 7 accomplishment and imagination, and 23 personality and temperament.

† "A Technique for Producing Ideas," by J. W. Young, Advertising Publications, Inc., Chicago, Ill., 1944, cites five basic steps in producing ideas in advertising. They are (1) gather raw materials, (2) mentally work over these materials, (3) the incubating stage where something besides the conscious mind does the synthesis, (4) the birth of the idea, and (5) final shaping and development. Prof. E. D. Smith in "Some Psychological Factors Favoring Industrial Inventiveness," *Mechanical Engineering*, Vol. 66, 1944, pp. 159–162, points out three steps; (1) period actively engaged in problem, (2) period not actively engaged on it but on something else, (3) period after solution working out details. Prof. E. D. Hutchinson in "Psychiatry," Vol. 2, August, 1939, pp. 323–332, points out four stages in solving a creative problem. They are (1) a period of preparation, (2) a period of renunciation or recession, (3) a period of insight, and (4) a period of verification, elaboration, or evaluation.

vidual characteristics are more evident. One prolific inventor believes there are "eight ways of doing everything" and insists on finding most or all of them before making a final selection. He frequently pages through an old book of inventions, not to copy, but to stimulate formation of mental images and association of basic elements. Another keeps a scrap book of his previous ideas and leafs through it for the same purpose. More frequently, engineers "search for power," that is, they try various types of motivation or sensitivity such as electric, hydraulic, chemical, mechanical, and electronic means. Various forms are tried for fit, like pieces of a jig-saw puzzle. For some problems, this stage may involve a great amount of work and usually is nearest completion when the situation seems the most hopeless.

3. *Period Resulting in the Intuitive Idea.*—It is the act of invention—the patent docket stage. Most often, the "flash of insight," as it is called by Prof. E. D. Smith,* comes during a period of relaxation or activity not associated with the problem. New ideas often occur at meals, when traveling, or while attending a social event. One inventor gets many ideas during dreams and keeps a drawing board near his bedroom to record the ideas before they are lost. This occurrence of ideas independent of direct activity on the problem appears associated with some characteristic similar to a subconscious mind. After outward activity of stage (2), the problem is continuously manipulated with elements of experience and knowledge until a solution suddenly emerges.

Occasionally, the idea will occur spontaneously as the result of a new experience. K. Paluev † likens this to a customer seeking some unknown article. He doesn't know what the article should look like although he does know what it must do. When the appropriate article is seen, it is suddenly recognized as capable of performing the necessary service. In other words, the inventor mentally stores well-formulated problems, and the instantaneous association of the requirements with a new experience leads to the act of invention.

There is still another conception of this stage. It is what Dr. W. R. Whitney ‡ calls "hunch," that is the intuitive use of some scientific data or laws before they are known. Hunch may also take the form of a stab or trial at solution. Some individuals, on being confronted with a problem, immediately think of an answer. Later mental activity often shows the hunch unable to satisfy the particular problem, but continued activity makes possible many successes.

Although various authorities describe the act of invention differently and find the individual steps involved difficult to analyze, they do agree that the speed of thought is very high, and that facility in this stage is dependent upon calling upon previous knowledge and experience. The greater the accuracy and completeness with which

* "Some Psychological Factors Favoring Industrial Inventiveness," by E. D. Smith, *Mechanical Engineering*, Vol. 66, 1944, pp. 159–162.

† "How Collective Genius Contributes to Industrial Progress," by K. K. Paluev, *General Electric Review*, Vol. 44, 1941, pp. 254–261.

‡ "Things I Have Been Thinking About," by Dr. W. R. Whitney, *American Magazine*, Oct., 1937; "Creative Engineering, Inventiveness, and Intuition," by Igor Sikorsky; pamphlet of Creative Engineering, A. S. M. E., July, 1944. pp. 3–6, also uses this conception.

owledge and experience are stored, greater the potential inventive ca-ity. In this respect, the substantial gress in creative work made ough engineering conferences ap-rs due to great collective knowledge d experience and the stimulation this vides each individual paritcipating.

4. The Idea is Shaped to Practical efulness.—Each element must be de-ed in a form that can be suitably nufactured, and the form must be portioned in proper relation to the icipated service. Calculations or del experiments may be required to termine the relations necessary. metimes all the work can be done by e engineer but, in any major de-lopment, the collective action of an gineering organization is employed take advantage of special skills and reduce completion time.

Great perseverance and optimism are quired in this stage to see the job ough, to inspire others, to maintain eir confidence, and to persist in the ce of discouragement, such as errors, al failures, and criticism. This is the 9 per cent of Edison's famous state-ent that inventions are 1 per cent in-piration and 99 per cent perspiration.

Selection of Engineers for Creative Work

It is generally agreed that some of e aptitudes which have an important fluence upon inventiveness are her-itary, but that the majority of apti-udes necessary are subject to develop-ent under proper environment rcumstances. Naturally it was in this ght that the Creative Engineering Program was founded and, in the ex-perience to date, there has been no vidence to the contrary. Actually, it as been found that most all good en-gineers possess a creative spark in some measure, and it has been possible to develop it to a greater extent than at first expected. This talent does not develop naturally in spite of surround-ings, however, and it has been difficult, therefore, to recognize and evaluate in young engineers with different back-grounds and of various degrees of maturity.

Some evidences of creative capacity are found in hobbies. The model-air-plane builder for instance may tire of making models according to the exist-ing designs, and proceed on his own to a new type, discovering the operating relations among the parts as he goes. Engineers brought up on the farm may also have had somewhat similar ex-periences in the repair or construction of farm machinery. These are good signs and are easily recognized. Once in a while an endeavor of this type has led to an actual patent of a scrap book of "ideas" which is even better evi-dence.

When the opportunity for hobbies has not arisen, as for many engineers who grew up in large cities, signs of creative capacity may be indicated by study of the characteristics associated with the aforementioned technique of synthesis. Perhaps of most importance is the knowledge pattern and quotient. By this is mean the knowledge and ex-perience applicable to the technique of synthesis and the degree to which they are present. There are three important parts to the knowledge pattern as re-gards creative work, *i.e.*, (1) scientific knowledge, (2), design curiosity, and (3) the ability to generalize experi-ence. The first, as mentioned earlier, underlies all engineering, and without it little engineering contribution can be expected. The term "design curiosity" refers to interest in engineering works, how they operate, and how they are

constructed. This interest provides a means for developing a sense of proportion * and a feeling for design strength, size, and power. The last, the ability to generalize experience, refers to the facility mentally of storing information accurately and in a pattern hat can be easily recreated and applied. Special reference to the act of invention is implied here.

In evaluating these three phases of the applicant's knowledge, it is recognized that the actual knowledge already acquired can be enhanced by further training; but the degree to which an experience is retained and the pattern of retention are not as easily trained, if at all, and are, therefore, significant.

It was mentioned previously that the characteristics of perseverance and optimism are also necessary in order to see a problem through to a finish in spite of difficulty and disappointment. Another important factor is constructive discontent. No matter how good his tools, and engineer will not create unless he possesses discontent with things as they are, either in themselves or their limitations, and has the desire to improve them.

Still another factor is the habit of using intuition in the solution of design problems. This habit involves strong imagination and a speculative and alert nature. The individual must be willing to take a chance or "stick his neck out." He thus develops the intensity of interest required to rise above the average and places faith in himself and his idea so it is seen through to a conclusion. Alertness is important for it assures awareness to the coming of an idea.

* "How Useful Is Your Sense of Proportion," W. E. Johnson, *Mechanical Engineering*, Vol. 60, 1938, pp. 481–484.

Not all inventions, as mentioned before, are the result of direct activity, but often an observed experience provides, through association, an answer to a different problem, that is, the invention is a by-product and opens up some new endeavor. Research inventions are often of this type. Alertness is also important because not every idea is the right one. By being alert to their coming and by using all measures that can be commanded for checking them, the right one can be singled out.

Besides these rather special characteristics, a number of general characteristics of importance to any engineering activity should be given consideration. Some of these are intelligence, business or engineering sense, energy and willingness to work, leadership, personality, and the ability to get along with others. To some extent, leadership, personality, and ability to work with and through others need not be present in the same degree for a highly inventive person as for others. However, in industry, very few individuals can be lone workers, and the man who possesses these abilities as well as creative ability can accomplish infinitely more.

Developing Methods of Selecting Candidates

The number of talents cited makes a rather impressive list and yet each is important in the part it plays. First attempts to select engineers possessing the right balance of these abilities were only moderately successful. A mechanical-aptitude test intended for the college level was tried with both gratifying and disappointing results. All the applicants rated in the upper 5 per cent of all persons tested, but there was no

correlation between test ratings and abilities observed during a 2-year period. It seemed that as much intuition might be required to select creative engineers as they were to possess. Over a period of a few years, however, a highly effective plan of personal interviews was developed. Instead of a single, short interview with one person, interviews lasting an hour or more were arranged for applicants with a number of older engineers who had daily experience with the training of young creative engineers. These interviewers met frequently to discuss candidates, and the progress of those selected. In that way they very soon were able to recognize signs of creative capacity, whether they could be defined in words or not.

In conjunction with this method of selection, other measures were tried, primarily as experiments to obtain a better measure of the talent itself. Even analysis of handwriting was considered. Samples of copy work and original work were obtained, but their analysis although positive in more than half the cases was often found to be entirely incorrect. Certain types of puzzles and short problems having engineering importance were also tried but these too were not found to be reliable enough. Some potentialities seem to be indicated in examinations which (1) measure knowledge of the fundamentals of physics in a nonanalytical way, (2) test design curiosity through test of observation, and (3) judge ability to generalize experience and recreate it by providing an experience new to all applicants, and by attesting their ability to apply it to several associated fields. Further exploration is needed to ascertain the effectiveness of this approach.

Present Program

Each year approximately 30 young engineers are selected for the program on a competitive basis. The interview method is used, taking into account the factors just discussed and recognizing that facility in the exercise of most of these factors can be developed with practice. A few engineers come to the program directly from the colleges, but the majority are chosen from those having completed a year or more experience in the Company's Testing Department. There are two important reasons for this: (1) The experience and contacts obtained in this work become of great value to these men in their engineering activities. (2) Test training also provides an opportunity for some of the creative instinct to assert itself and in that way aids selection. For interested candidates whose backgrounds show little evidence of creative ability, special trial test assignments in the design of new testing equipment are arranged and very often these assignments bring out unsuspected talent.

The principal part of the training provided consists of an organized series of assignments on contributing engineering work under the direction of senior engineers acknowledged to possess intuitive, creative ability. In the course of a year or longer, each young engineer works on four or five assignments in turn. The engineer to whom he is assigned supervises his work and takes special care to develop stability and unity through discussion and personal example. In so far as possible, the young engineer is given complete responsibility for the design of a device so he may gain the experience and confidence essential to a productive career.

This follows the method of appren-

ticeship mentioned earlier but has several important differences. The frequency of assignments makes it possible to have each man work on several different products and in several different fields, and thus assures an opportunity for a "nonhabitual approach." Assignments also vary from pure development to production-design engineering and, where possible, are graded in responsibility and guidance so the engineer comes to depend upon himself as he gains experience in the program. Perhaps even more significant is the supervision of several different senior engineers. Much as an artist is developed by association with a master, so the creative engineer develops in his work with the senior engineer. But work with a number of these men allows the trainee to gain inspiration and technique from all, without the liability of losing his individualism in the tendency to emulate any one of them.

Those selected spend a half day a week in class on company time during 35 weeks of the assignment period. Although the first classes were established somewhat as an afterthought, classroom work is now considered a valuable asset to accomplishing the most through the assignments. The classroom develops an *éspirit de corps* that is of immense value in the conduct of assignment work, and also provides a means for "sharpening" the engineers "tools" and for emphasizing the objectives to be attained.

Classes are supervised by young graduates who devote most of their time to the work. This provides an excellent opportunity to develop qualities of leadership in the few who can be given this privilege and assures a close relationship with the needs and ambitions of the classes. Whatever time the supervisor has to spare is spent on engineering problems in a junior consulting capacity.

The class work is quite varied. Considerable emphasis is placed upon understanding the fundamentals of physics which underlie engineering. Subjects covered include dynamics, elasticity, thermodynamics, heat transfer, hydrodynamics, electrical circuits, electrical machinery, and basic electronics. Lectures on these topics are given by a large number of older engineers from many departments. Recently, a new method of presentation has been tried. Instead of following the classical analytical-case method, some lectures were presented from a more general viewpoint, attempting to outline a whole field and stressing the "physical picture," the various methods of attack, and the applications. It appears that creative engineers are more interested and absorb more with this approach and it seems to promote their facility for generalizing experience.

Home problems requiring 6 to 10 hours, are assigned each week. Approximately one-half of these are chosen to get the most out of the study of fundamentals. The other half deals with design questions of interest to the company's engineering departments. New, live problems of this type stimulate creative thinking and the "nonhabitual approach," and help each young engineer develop a technique of synthesis suited to his gait. Solutions to these design problems are often of use to the department concerned.

Problem solutions are written up as engineering reports to develop proficiency in presenting engineering studies. These reports are constructively criticized for technical excellence, originality, and presentation. Numer-

ical grades are usually assigned, but grading of some design problems is difficult because a successful idea cannot always be developed in a weeks' effort. Longer problem assignments and overlapping assignments help make it possible to get answers to every problem assigned and, in that way, give the engineers confidence in approaching any new problem. Sometimes solutions are evaluated in class seminars, led by a representative from the interested department. Such discussions enable the young engineer to see the problems from different aspects and in the light of different practice and principles.

A good portion of the class time is spent in inspection of manufacturing departments. These trips are augmented by talks by shop men for answering questions and bringing out important points. In this way the young engineers' knowledge of materials and factory processes is furthered. Other subjects covered in the classroom period include imformative talks on various phases of engineering, company policy, and patent law, training in freehand sketching (which is a valuable tool in design work), and review of design progress in given lines of activity through study of developmental models and examples of the application of new ideas.

During one month of the classes, each man works on one or more inventive design projects of his own selection as part of the homework. Those who wish to construct working samples of their design in their spare time have at their disposal a well-equipped machine shop in a local technical high school. These projects are good indicators of the direction as well as the magnitude of a man's ability.

A short evening course in the "engineering approach to human relations" is also conducted. This course is an indication that technical skill or inventiveness alone is not enough—a young engineer must sell his ideas and himself in order to secure co-operation and results with those with whom he works.

Results Achieved

In the 8 years the program has been operated, a total of 133 men have graduated from it. One hundred and ten or 83 per cent are still with the company, eleven having gone into the armed forces and the others having left the company voluntarily.

The graduates have been of two types. A small proportion has possessed a very high degree of inventiveness and has been interested only in developmental phases of engineering. They thrive on new problems but have little interest in carrying through to a finished product once the method of accomplishing the result is known and proved. A second majority type follows the objective of the program more closely. They are design engineers who apply ingenuity as the proper stages of the design problem but who get immense satisfaction from carrying the work through to a finished product ready for delivery to the customer.

In both groups there have been many examples of broad individual achievement considering the comparatively short experience of the graduates. Most of them have several patent dockets by the time their rotating assignments are finished and continue in this direction on their more permanent assignments which follow. The percentage of dockets which are carried through to patents is not obtainable at present because so much of the work

has been on projects of military importance. The contributions made and the responsibilities assumed during the war have, however, been large. In all probability many of the developments sponsored could not have been undertaken without this pool of creative engineers from which to establish and expand engineering forces. Large percentages of the graduates worked on radar, gun computers and directors, superchargers, and jet propulsion.

The program has, it is believed, definitely proved itself through the many important contributions of its graduates. Naturally, like most training programs, it has been possible only to provide an introduction to the field of creative engineering. Each man has received encouragement to do this type of work, has gained some practice in it, and has in some measure "glimpsed the horizon." Except for departmental supervision and stimulation, he is left on his own to continue his study and development as he rises in professional stature. It is felt that the full potentialities have not yet been realized because of the period of years required for full expression of the talent. Ultimate expectations depend upon further progress in understanding the abilities sought and in providing encouragement and developmental of these abilities earlier in the educational system.

The program was curtailed in 1944, because of the scarcity of engineering talent for direct production of war products. Classes have already been resumed, and there is every indication that they will prove equally as valuable in reconversion and the peacetime economy to follow as they have during the war.